Archaeological Monitoring
the Demolition and Dismantling-Commemoration Project, Marshall Lime Kilns, Upper James and Red Hill Expressway, Regional Municipality of Hamilton, Ontario

Submitted to
Regional Municipality of Hamilton-Wentworth
Hamilton, Ontario

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December 1994

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1.0 STUDY BACKGROUND AND OBJECTIVES

by C. Andreae and R. Williamson

In 1982, the remains of two nineteenth century lime kilns were discovered in the area of a proposed interchange for the future Red Hill Creek Expressway in the City of Hamilton. These features constitute the remains of two of the three kilns operated by Marshall Lime Kilns, on Lot 14, Concession 7 of the former Barton Township, which was incorporated within the Regional Municipality of Hamilton-Wentworth in 1973 (Figures 1 and 2). The current address of the property is 1121 Upper James Street.

In 1989, Archaeological Services Inc. was retained by the Red Hill Creek Expressway Project Office (RHCEPO), Regional Municipality of Hamilton-Wentworth, to document a derelict powder magazine, to assess the archaeological potential of the kilns and to undertake an archaeological survey of the remainder of the property. This study was undertaken in conjunction with Historica Research Limited and a report was prepared in which it was recommended that the kiln ruins should be exposed, stabilized and left in their present location, should this prove technically feasible in the expressway design (Archaeological Services Inc./Historica Research Limited 1989).

In order to comply with these recommendations, the Expressway Office retained Archaeological Services Inc., in September of 1991. The study was undertaken in November 1991 in conjunction with Historica Research Limited.

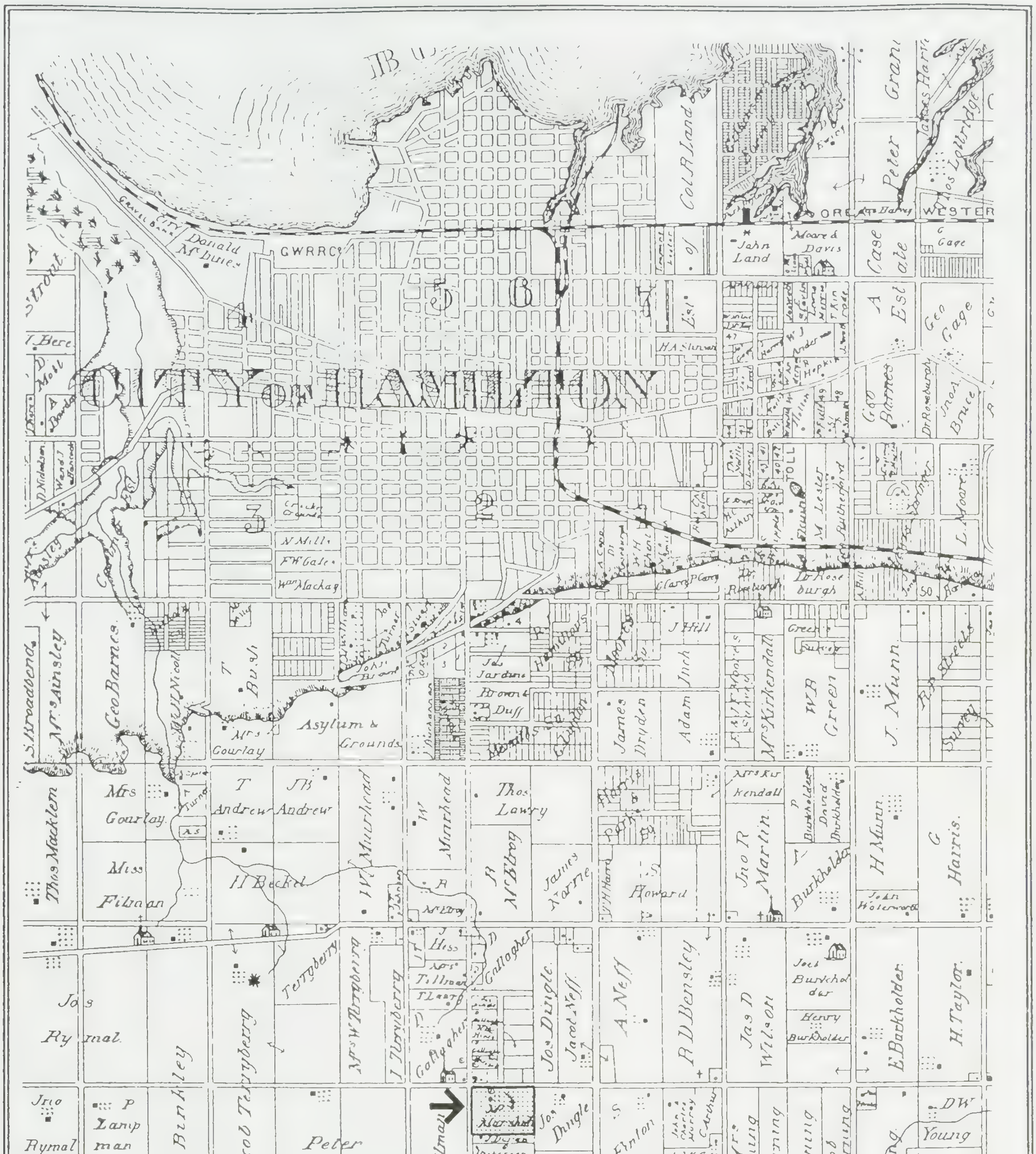
Three kinds of documentary research were undertaken, including archival research directly concerning the history of the Marshall operation and comparative research concerning the design and operation of late nineteenth century lime kilns. Various techniques used in the excavation of historic lime kilns in Britain, Canada and the United States were also reviewed although no methodologies distinct to this type of structure were identified. Summaries of this research were provided in the final report of the 1991 excavations.

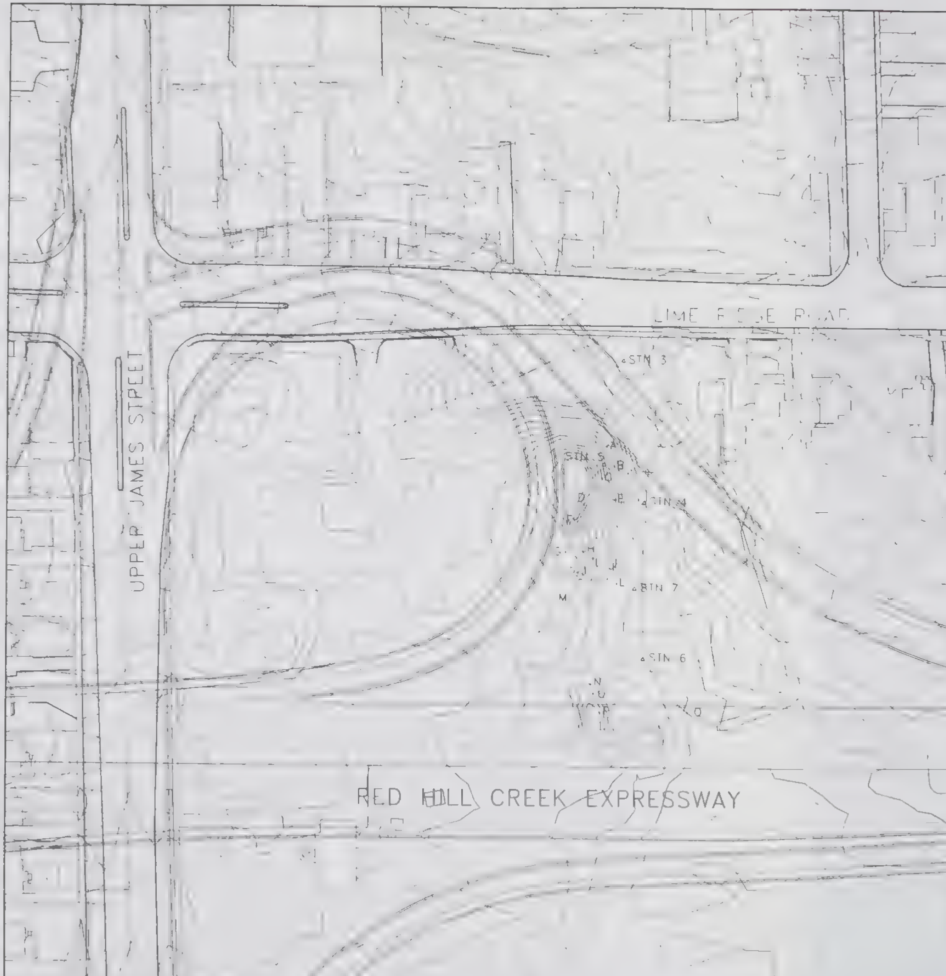
As a result of that work, it was recommended that the remains of the kilns be protected *in situ*, if possible and failing that, that they be recorded during a controlled demolition. Subsequent discussions between the RHCEPO and the Hamilton Local Architectural Conservation Advisory Committee (LACAC) resulted in a further plan for the partial disassembly and reconstruction of Kiln One, as it was decided that destruction of this structure was unavoidable. The resulting mitigative activities are the subject of this document. These activities were also undertaken in conjunction with Historica Research Limited.

The 1994 work was conducted between June 27 and July 11. The research goals of the demolition/dismantling project were to:

- achieve an understanding of the method of firing used in Kiln One; especially with respect to the use of natural gas;
- plot the profile of the stack lining in order to see how Kiln One compared with typical kilns of the era;

Figure 1: Map of Barton Township showing location of the Marshall lime burning operations on part of Lot 14, Concession 7. Source: *Illustrated Historical Atlas of the County of Wentworth*





KEY TO MAP SYMBOLS

STN 3 – STATION 3 (217.96 m ASL)

STN 4 – STATION 4 (219.01)

STN 5 STATION 5 (224.55)

STN 6 – STATION 6 (221.37)

STN 7 – STATION 7
(ELEVATION NOT AVAILABLE)

A LIME KILN #1
– TOP OF RETAINING WALL (221.45)

B – LIME KILN #1
NE CORNER, EAST FACE (224.55)

C – LIME KILN #1
– TOP OF EAST RETAINING WALL (223.42)

D – END OF BANK AT CUT (226.70)

E BEDROCK (220.77)

F – TOP OF BANK BETWEEN LIME KILN #1
AND #2 (227.01)

G NW CORNER OF LIME KILN #2
(NO ELEVATION AVAILABLE)

H – NE CORNER OF LIME KILN #2
(NO ELEVATION AVAILABLE)

I LIME KILN #2
– NORTH FACE (222.96)

J LIME KILN #2 – TOP OF BANK ON
WEST SIDE OF KILN (223.94)

K – LIME KILN #2
EAST FACE (222.09)

L PATH IMMEDIATELY EAST OF
LIME KILN #2 (220.74)

M RIDGE CONNECTING LIME KILNS
#1 AND #2 (225.75)

N TOP OF BANK (224.82)

O – TOP OF BANK (224.68)

P – TOP OF BANK WEST OF
STATION #6 (224.35)

Q – POINT ALONG PATH (222.10)

NOTE

1994 ELEVATIONS POST–1991 WORK

Archaeological Services Inc AutoCAD Release 11	PREPARED UNDER CONTRACT BY ARCHAEOLOGICAL SERVICES INC., HISTORICA RESEARCH LIMITED.	Location of Marshall Lime Kilns Upper James and Lime Ridge Hamilton, Ontario	Figure 2	DRAWING BY DELCAN CORPORATION DRAWING REVISED BY: A. ALLAN, 16 NOV. 1994

- examine the method of Kiln One's construction in order to determine its operational characteristics; and
- determine how much of Kiln Two remained intact.

Prior to the onset of the 1994 work on Kiln One two assumptions were made:
- the design of the kiln was symmetrical and the two furnaces were functionally similar;
- the kiln stack was filled with unstratified material resulting from the demolition of the kiln after 1927. No stratigraphic analysis would need to be undertaken of this fill.

Most of the excavation was undertaken using a Gradall since a considerable amount of fill, including large, heavy stones, had to be removed in a short period of time. Shovel work and trowel cleaning were subsequently used in a number of areas and to prepare specific architectural features for detailed recording and photography.

In Kiln One, the investigative process involved the removal of two levels to the point at which the furnaces were encountered. The furnaces were excavated individually. Finally, the area between the furnaces and the bottom of the kiln was sectioned vertically and the front of the kiln was cleared so that the support arches could be disassembled and stored for future reconstruction as a monument. By the conclusion of the excavation, Kiln One had been partially dismantled and the remainder demolished.

In the case of Kiln Two, the exterior was partially exposed. The south wall, at the location of the furnace, was excavated to the approximate level of the working floor. The east wall was exposed to the base of the access arch and the arch was cleaned to reveal the draw hole. The north wall was also partially excavated in order to examine the character of the wall and confirm the existence of a possible furnace opening. The stack was excavated to a depth of about half a metre (two feet). No destructive investigations were conducted on the kiln body. At the conclusion of the excavation, Kiln Two was reburied.

Other structures associated with the kiln, namely an earth ramp, powder magazine and three quarries, were identified in previous studies. Descriptions of these features are available in *Archaeological Investigation of the Marshall Lime Kilns, 1121 Upper James Street, City of Hamilton* (Historica Research and Archaeological Services Inc. 1992) and are not included herein.

The remainder of this report is divided into six sections. Section 2.0 provides a discussion of the technology of lime burning at the beginning of the twentieth century, in order that the structural remains may be described in terms of their industrial context. Sections 3.0 and 4.0 provide descriptions of the results of the site excavation. Analysis of the kilns is provided in Section 5.0 and recommendations are presented in Section 6.0. Appendix A is a detailed description of the dismantling of Lime Kiln One and contains recommendations for the curation of the stone and reassembly of the draw arch.

2.0 MANUFACTURE OF LIME

by C. Andreae

2.1 Chemical Process

Pure calcium carbonate ($CaCO_3$) – the primary material in limestone – will begin to decompose into carbon dioxide (CO_2) and calcium oxide (CaO) at a temperature of 898°C. This process, known as calcining, is undertaken commercially by burning limestone in lime kilns. Calcining takes place, through a chemical process expressed by:

$$CaCO_3 + \text{heat} = CaO + CO_2$$

Calcium oxide, also known as quicklime, is a caustic, unstable compound that reacts vigorously with water. Quicklime has some commercial applications, but more commonly it is converted into calcium hydrate ($Ca(OH)_2$), a more stable product that is also called slaked lime. The process of slaking, or hydration, occurs when water is mixed with quicklime as described in the equation:

$$CaO + H_2O = Ca(OH)_2 + \text{heat}$$

Only the reaction of calcination bears directly on the operation of the Marshall lime kilns and is examined in detail in this report. However, as will be described, the quality of hydrated lime is dependent upon the calcining process. Three variables had the most effect on calcining in 19th century kilns: the type of limestone, the temperature, and the effective removal of carbon dioxide from the kiln.

2.1.1 Limestone

The stone that was quarried in Barton Township, known as Lockport dolomite, is very pure and dark brown in colour. Chemically, dolomite ($MgCa(CO_3)_2$ or $CaCO_3,MgCO_3$), is a double carbonate of lime and magnesia. Both dolomite and limestone can be used as a raw material in lime manufacture; dolomite has the advantage of calcining at a lower temperature than pure limestone. The high magnesium content in dolomite is not considered an impurity and is actually a beneficial ingredient in some lime plasters.[1]

Heat acts upon a naturally coarse, porous stone more rapidly than a dense, finely crystalline stone and consequently can be burned more rapidly at a lower temperature, and in theory, small stones can be burned more readily than large stones. In nineteenth century practice, however, large sizes were preferred by lime burners as more practical, since fine material and small stones could clog the flow of hot gases through a vertical shaft kiln. The common practice was to use what are called "one man stones", measuring about eight to ten inches in diameter.[2]

2.1.2 The Temperature

Although pure calcium carbonate will calcine at 898°C, the actual composition of the stone will affect the minimum temperature at which decomposition occurs. Some dolomites for example will calcine at 550°C. Theoretically, all limestones can be properly burned at a temperature of about 880°C, provided that a longer period of time was allowed for calcining. As might be expected, a lower temperature results in considerable savings in fuel costs. Indeed, by 1900, it was found that to burn one ton of magnesium stone (dolomite) required about 88 pounds of coal while a high calcium stone (pure limestone) required 110 pounds of coal.[3]

Operating a kiln at the correct temperature was critical for the economic operation of a lime works. Kilns were operated at the highest practical temperature since the rate of calcining was directly proportional to kiln temperature. Not only did this allow for greater production, but the more quickly limestone was burned at a high temperature, the more readily it slaked. The maximum calcination temperature for a pure high calcium lime was about 1,300°C while for a pure magnesia lime, the temperature was between 900-1,050°C and never above 1,100°C. Within industrial applications, these temperatures were not especially high. Metallurgical industries, such as iron and steel, frequently required furnaces with much higher operating temperatures.[4]

The operation of a kiln at too low a temperature was unlikely to occur. If the temperature was too low, the cores of larger rocks were left unburned and would subsequently not hydrate. The correct design of the shaft and the furnaces and the characteristics of the raw materials were important to ensure a kiln functioned well. Fortunately, under-burned lime was not a waste product, since it could be reintroduced as a kiln charge and reburned.[5]

It was also important that lime never be burned above its recommended temperature. Above this level, stones might "over-burn" and produce a glazed surface on lime lumps that would hinder, or even prevent, hydration or slaking. If over-burning occurred, the product would be considered waste material and discarded, as it could not be reburned. In general, some over-burned lime was produced in the kiln and had to be separated from properly hydrated lime. If it was left in the slaked lime, the small quantities of over-burned lime were apt to become hydrated and to expand after the lime plaster had set, thereby causing "popping" or "pitting" on the surfaces of plaster walls.[6]

2.1.3 Carbon Dioxide

Calcination produced considerable volumes of carbon dioxide (CO_2) in the kiln. With a magnesium carbonate, such as the dolomite of Barton Township, carbon dioxide accounts for more than half (52.4%) of the stone's weight. As the concentration of CO_2 rose, the temperature of the kiln had to increase to maintain the reaction. If the CO_2 level became too high, the process of calcination could reverse, causing the CO_2 and lime to recombine and to form calcium carbonate, in a phenomena known technically as "recarbonating".[7]

The simplest way to reduce the CO_2 concentration was to let more air enter the kiln. This, however, increased the kiln temperature and the risk of over-burning.

A more common method to reduce CO_2 levels was to introduce jets of steam or water into the hottest part of the kiln. Although the technique worked, the underlying reasons for its effectiveness were not well understood. One contemporary theory suggested that water broke down on contact with hot fuel into oxygen and hydrogen. The hydrogen travelled upwards in the kiln stack until it recombined with oxygen. The reformed water vapour produced new heat higher up in the kiln, which resulted in an increase in the draft and the removal of CO_2. A second theory suggested that water reacted with carbon fuel to produce carbon dioxide and hydrogen. The hydrogen, in turn, burned to produce super-heated steam, which diluted the CO_2 concentration in the kiln.[8]

Whereas the chemical reaction was imperfectly understood, the practical knowledge of the beneficial effect of introducing water into the kiln was well known by the 19th century. Indeed, various techniques and traditions had evolved to increase the water content of a kiln. Wood was considered the ideal kiln fuel since burning wood produced large quantities of steam. In small operations, lime burners preferred to burn in the winter and spring when limestone was most saturated with water. This was not an economical solution since additional fuel was consumed in expelling the moisture.[9]

2.2 Kiln Design

2.2.1 Type and Operation

The two Marshall lime kilns were of a design known as the "vertical, separately fired continuous kiln" or, less commonly as - "the continuous kiln with external grates" (Figures 3-6). The other common design type was the continuous kiln with mixed feed (Figures 7 and 8). These types were both shaft kilns and were sometimes referred to as draw kilns. Together, they accounted for virtually all lime production by 1900, although farmers occasionally manufactured a very crude lime by burning stone in heaps on open fires or in rudimentary pot kilns. While new industrial kilns were introduced by the end of the 19th century, they failed to have any impact on kiln design in Ontario.[10]

Separately fired kilns had a number of advantages over mixed feed kilns. First, the lime burner had more effective control over the burning process and secondly, no mixing of fuel, ash and lime occurred. Moreover, about 75-80% of the output of a mixed feed kiln was marketable while in a separately fired kiln, 90% was marketable.[11] On the other hand, mixed feed kilns were cheaper to construct, somewhat more economical with respect to fuel and more rapid in operation.

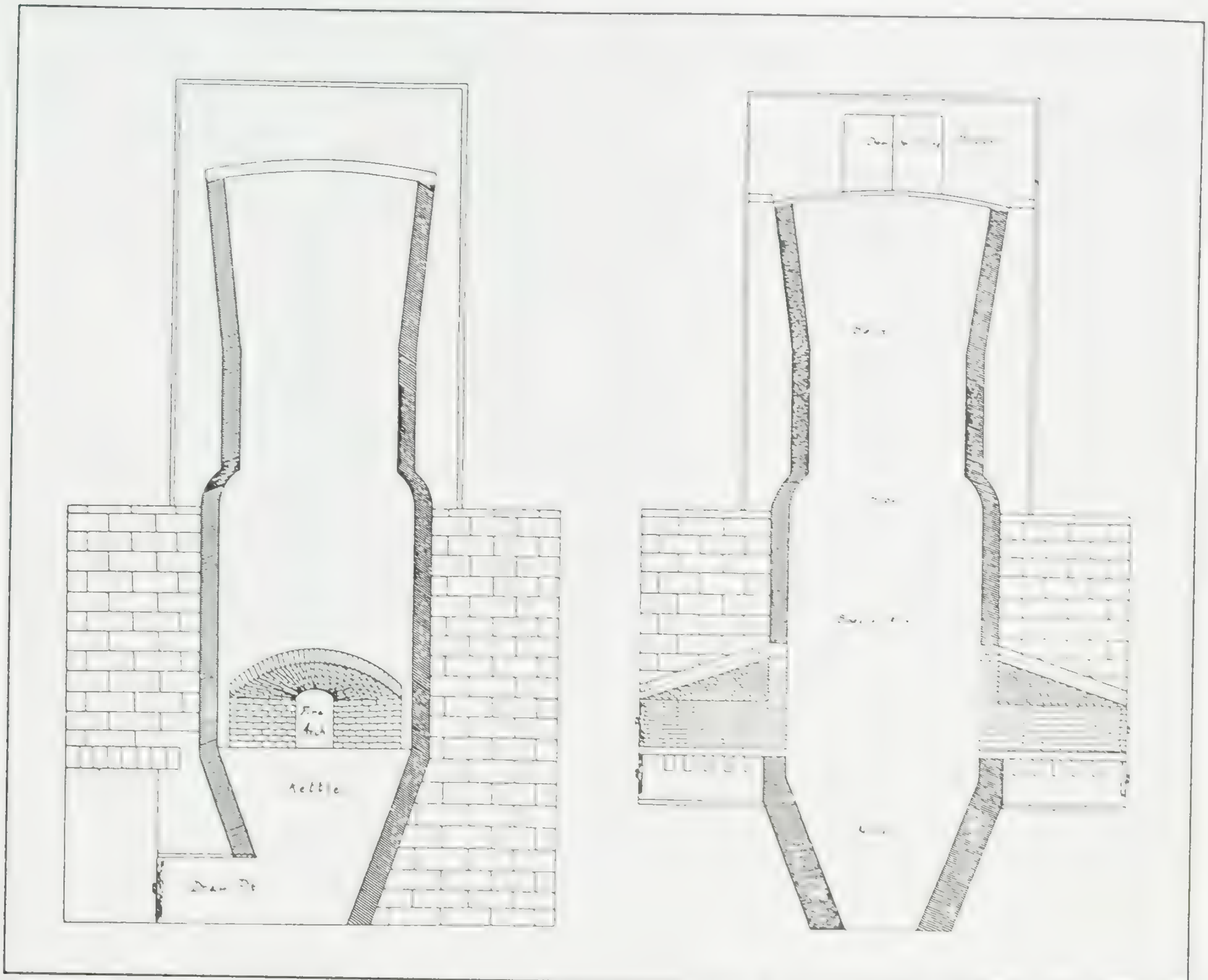


Figure 3: Components of one style of vertical, separately fired, continuous kiln. Source: Heinrich Ries, "Lime and Cement Industries of New York," 1901.

The shaft of a separately fired kiln contained four distinct zones or areas (Figures 3-5):[12]

i. The hopper, designed to store a sufficient quantity of stone to ensure efficient operation;

ii The preheat zone, tempering zone or barrel where stone was dried and brought up to calcining temperature;

iii. The calcining or burning zone in the body of the kiln; and

iv. The cooling zone, cooler or kettle where lime was cooled before discharge.

A kiln's capacity was determined by such variables as the type of the limestone feed, the structure's dimensions and the fuel. By 1900, a typical large separately fired kiln in Ontario would have had a base of about 18 by 22 feet and would have tapered slightly to a height of 53 feet. It

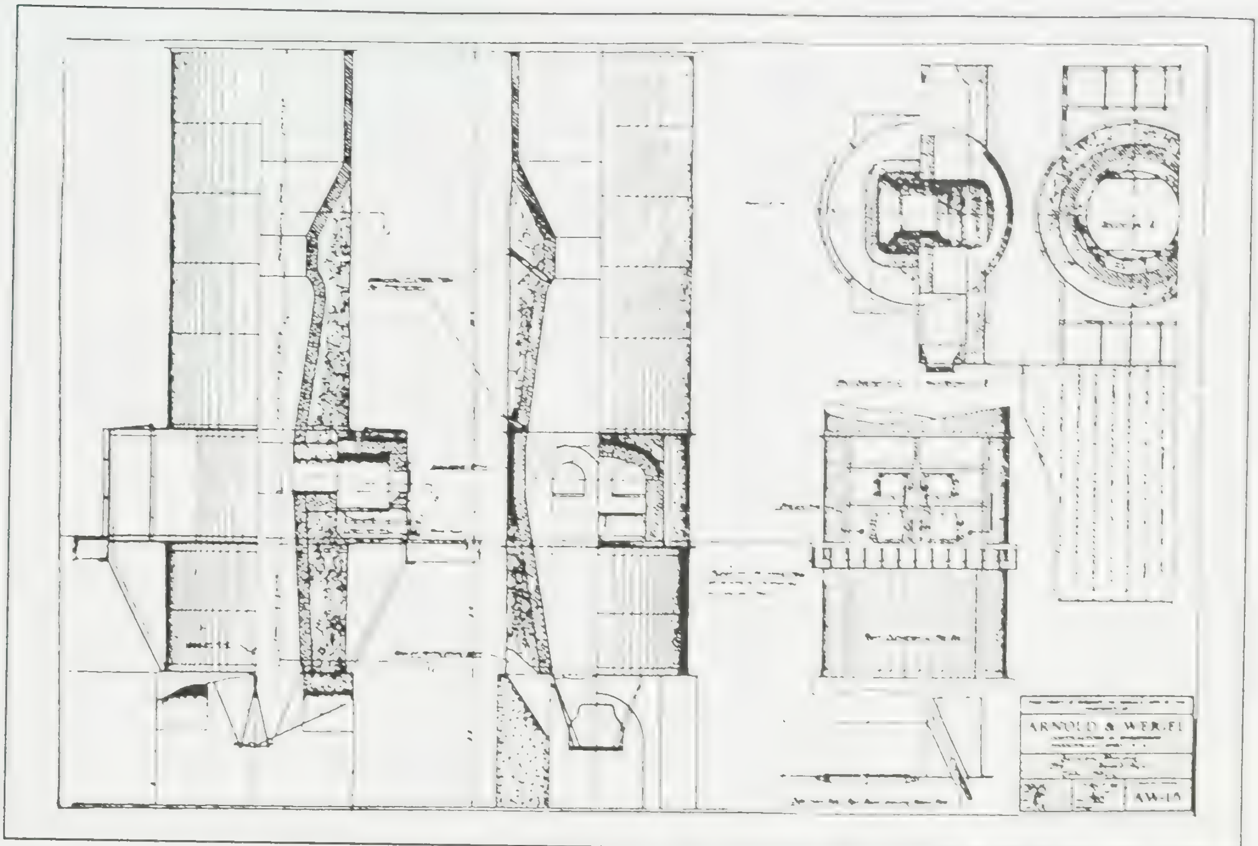


Figure 4: Early 20th century vertical, separately fired continuous kiln with steel shell. Source: *Pit and Quarry Hand Book*. 1927 ed., p. 381, 383.

would have had a processing capacity of 500 bushels of lime per day. Improvements to kilns in the 20th century concentrated on improvements to operating efficiency rather than to larger capacity. Indeed, while steel kilns of the 1920s were smaller than the older stone kilns, they were more efficient. A 38 foot steel kiln had a daily capacity of 400 bushels of lime per day and standard steel kilns were up to 50 feet tall.[13]

2.2.2 *Materials*

Nineteenth century kilns, such as those on the Marshall property, consisted of a refractory brick-lined stack supported by an exterior stone casing (Figure 6). By the early 20th century, modern kilns were usually cylindrical iron structures lined with refractory brick (Figures 4 and 5).[14] Refractory brick was required to provide a lining that would resist high kiln temperatures and would provide a smooth surface, which would not interfere with the downward flow of materials in the kiln, or chemically react with the calcining process. By 1900, several types of refractory brick were produced, the two most common of which were silica and fire clay bricks (Figure 8).[15]

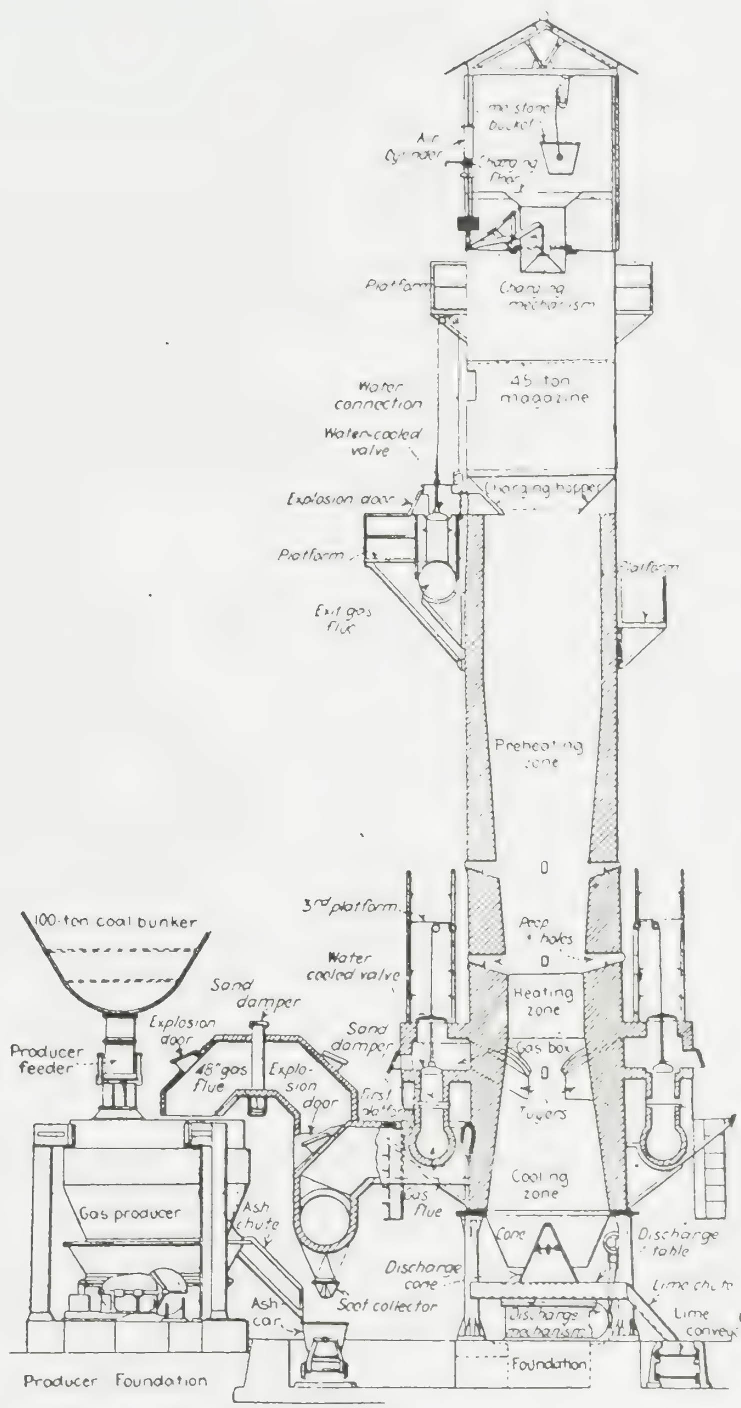


Figure 5: Mount Kiln; a gas fired early 20th century vertical, separately fired continuous kiln. Source: *Pit and Quarry Hand Book*. 1927 ed., p. 381, 383.

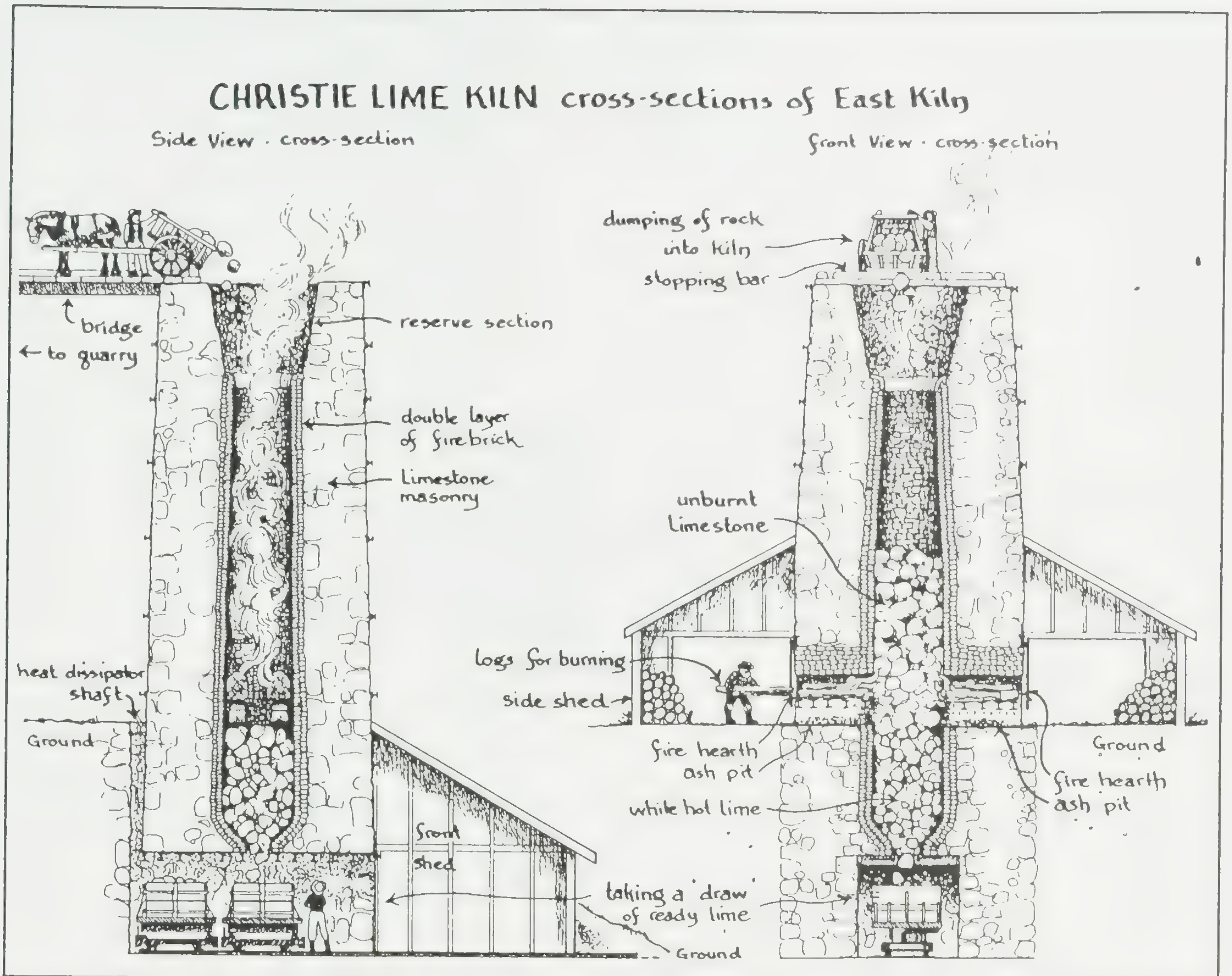


Figure 6: Reconstruction of the separately fired continuous kiln at the Christie lime kiln, Halton County, Ontario.
Source: Halton Region Conservation Authority, "The Christie Lime Kilns Report." By Y.S. Kangas & M. Lane. 1978.

By the 20th century, it was common practice to line the preheating, calcining and cooling zones with high grade fire brick. These could be backed with common red brick or ideally, with second quality fire brick. In the low temperature upper part of the shaft, it was usual to have a nine inch course of first quality fire brick butted against 16 inches of second quality fire brick. In the high temperature area, two 12-inch thicknesses of both first and second quality fire clay brick were recommended.[16]

The arches and bridge walls of fireboxes were generally constructed of first quality fire clay brick.[17]

The standard fire brick was nine inches long, 4½ inches wide and 2½ inches high and weighed seven pounds. The standard ring brick had an inner edge of four inches and various other key

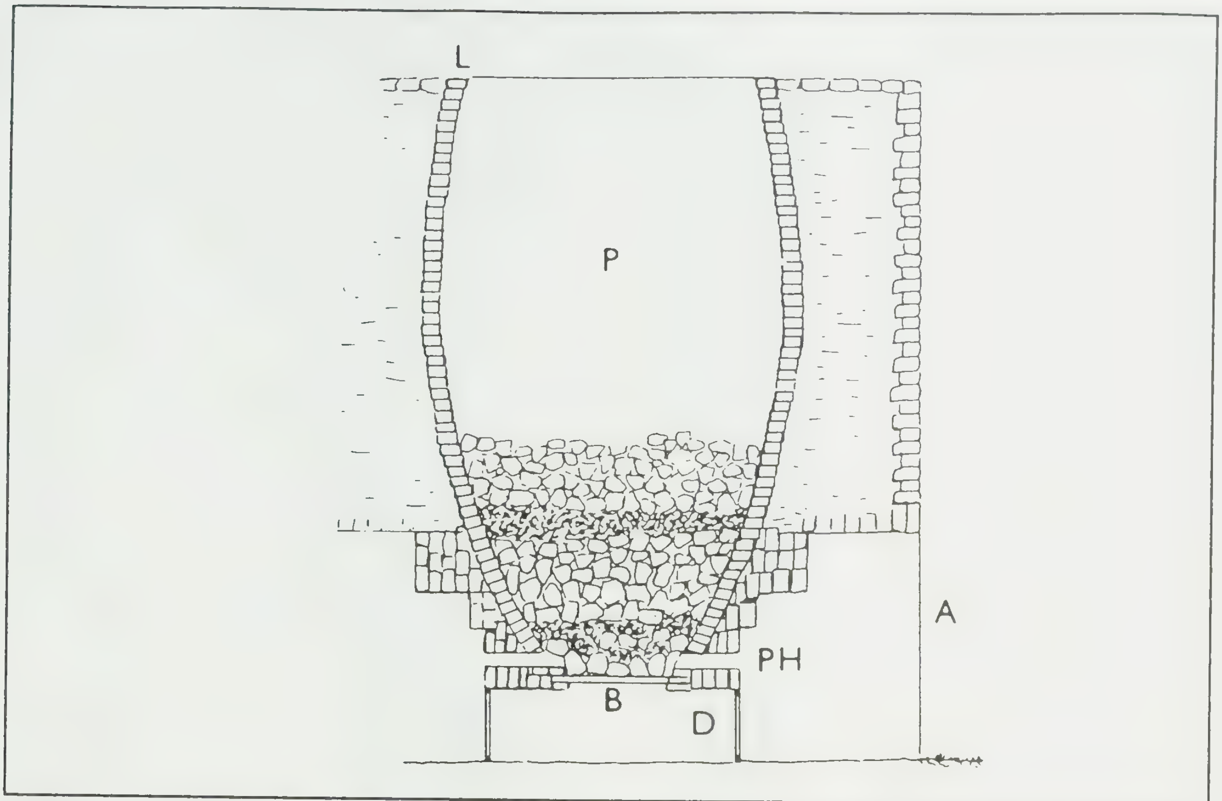


Figure 7: Vertical, mixed feed continuous kiln, showing limestone and coal in alternate layers. Key: P-kiln pot; L-stack lining; PH-poke hole; A-access arch; B-support bars; D-draw hole.
Source: Richard Williams, *Lime Kilns and Lime Burning*, 1989.

blocks were designed with one end varying from about 2½ to 4 inches in one-half inch increments (Figure 9).[18]

In low temperature areas, regular clay brick could be used. Generally, the hopper was lined with paving brick to better resist the abrasion of limestone being dumped into the bin.[19] Common brick could also be used as a backing to refractory brick and in the lower parts of the cooler.

Lime mortar, which bonded strongly when maintained at a cool temperature, was used to provide strength although it could not be used where it would be exposed to heat. Fire clay mortar was used with most refractory fire clay brick. Care had to be taken to make sure that the mortar would not fuse at the temperature at which the furnace was used. Instead, it was supposed to burn to cinder thereby knitting the whole structure together. Joints were to be eliminated wherever possible and very little mortar was to be used between the bricks.[20]

Figure 8: Vertical, mixed feed continuous kiln, showing refractory lining and fill in kiln body. Source: International Textbook Company. *Manufacturer of Cement,* 1902.

2.2.3 Shaft Profile

The kiln shaft had to be designed to allow the easy flow of material through the kiln and to ensure maximum contact between the stone and the heat source. The temperature changes throughout the shaft had to be as even as possible in order to prevent areas of over- or under-heating. Generally, the kiln was narrow at the top, widest at the calcining level and narrow again in the cooler (Figures 3-8). Builders sometimes added special shapes and baffles to improve the

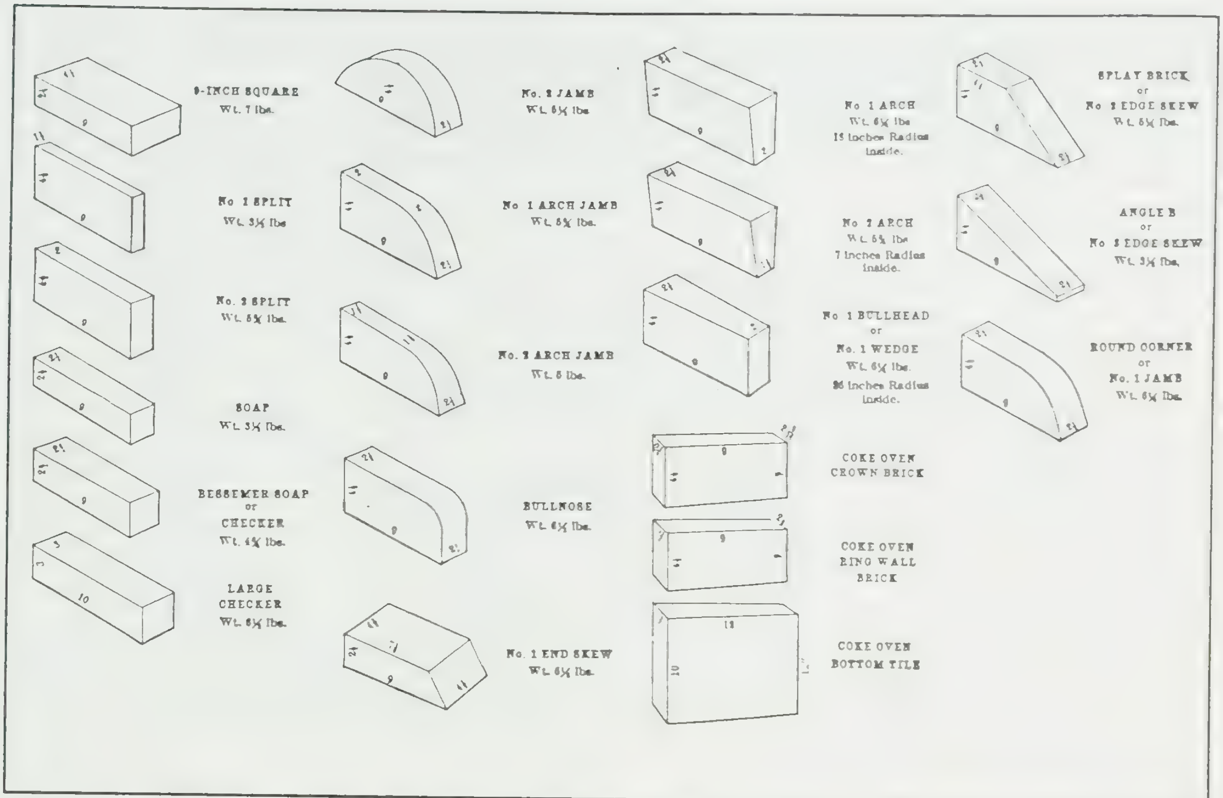


Figure 9: Standard shapes and sizes of refractory brick. Source: F.T. Havard, *Refractories and Furnaces*, 1912, p. 335.

kiln's performance. The design shown in Figure 3, for example, has a region called the hips that was suppose to concentrate the heat and ensure proper calcining.[21]

The cross-section of the stack was not circular throughout. Most kilns changed from circular at the top of the pre-heating zone to rectangular at the furnace level, thereby allowing space for the passage of flames. Moreover, the narrowest section of the shaft coincided with the hottest zone so as to ensure proper calcination of the rock in the middle. The stack gradually became square below the eyes of the furnace.[22]

2.2.4 Furnace Design

2.2.4.1 Fuel

Wood, anthracite or bituminous coal, peat, coke, producer (coal) gas or natural gas could serve as the fuel in a limestone kiln. The precise choice of fuel to use was dictated by availability, cost, type of kiln, control required in the kiln during burning and the quality of the end product. Each

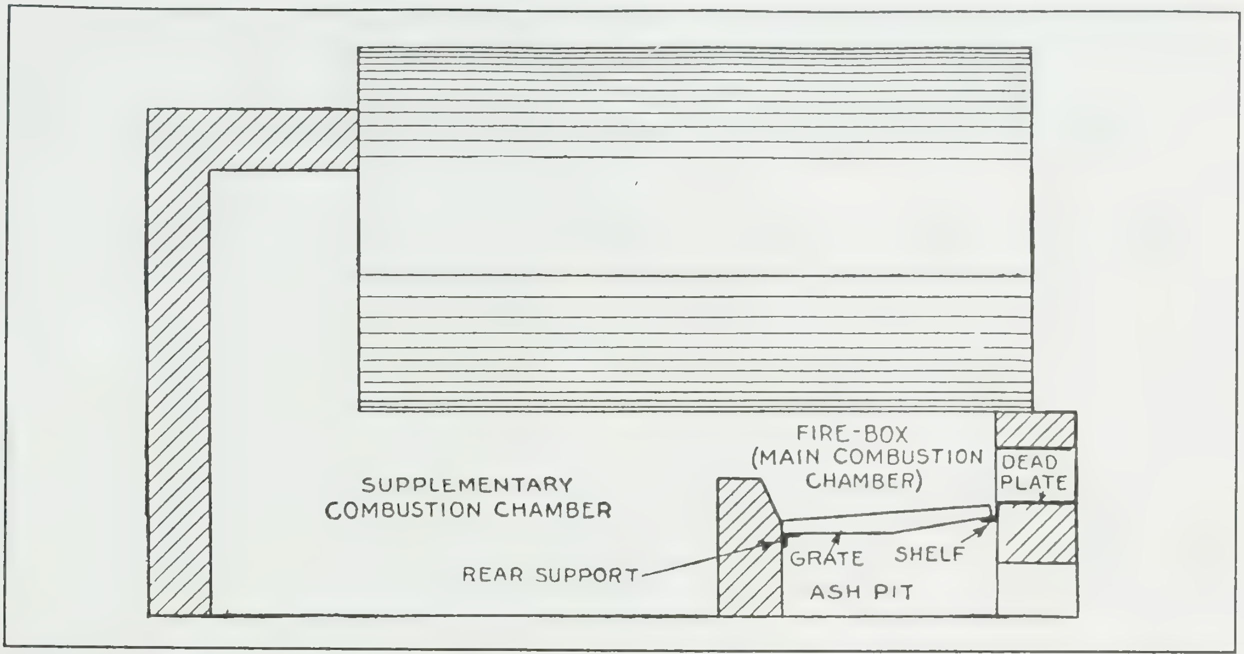


Figure 10: Layout of externally fired furnace for horizontal boiler. Although this drawing depicts a boiler setting, the furnace layout and components were similar to that of a lime kiln.

fuel had advantages and disadvantages, although as late as 1915 one writer noted that the relative advantages of gas, coal and wood as kiln fuels had yet to be perfectly established.[23]

Wood fuel, because of its great moisture content, produced long flames and consequently resulted in effective heat distribution throughout the furnace charge. Its high moisture content also assisted in driving off carbon dioxide. In 19th century Ontario, wood was cheap and readily available. One estimate indicated that 400 bushels of lime required seven cords of hardwood. Another estimate stated that 75 barrels (about 320 bushels) of lime required eight cords of wood at $2.00 per cord. By 1900, wood had become scarce and too costly to be employed as a fuel in lime burning.[24]

Some lime industry authorities have noted that coal would never have been used as kiln fuel if it had not been for the impossibility of obtaining wood in many districts. Indeed, the short flame and hot fire that resulted from using coal resulted in over-heating near the furnace and under-heating just above the fire zone. These characteristics could be improved by using a forced draft, which was achieved by blowing steam in through the fire grates. Otherwise lime kilns generally relied on natural draft that was seldom very intense. Once kiln operators understood the correct way of burning coal, however, it was found to be more economical than wood in both fuel and labour. By 1900, half the kilns in Ontario were using coal, most of which was imported from the United States, mainly from Pennsylvania.[25]

The earliest natural gas lime kilns in Ontario appear to have been converted from two wood-fuelled kilns near Port Colborne in 1890. The owner found that gas increased the daily capacity

of the kilns, resulting in lower operation costs. By 1900, large gas fields had been discovered within a reasonable distance of Barton Township and several lime burners, including the Marshalls, took advantage of cheap natural gas to fire their kilns. By 1913, James Marshall owned 24 natural gas wells in Seneca Township (today the Town of Haldimand including the village of Caledonia).[26]

The type of fuel did not superficially affect the shape of a kiln since modifications could readily be made to the furnace. Indeed, standard kilns, sold in the 1920s, could be adapted to burn wood, coal, oil or gas fuel.[27]

2.2.4.2 Furnace Design: Coal, Wood

The burning of solid fuel consists of a primary combustion, producing heat and gases, followed by a secondary combustion in which the gases are burned. In a separately fired kiln, primary combustion occurred in the firebox while, ideally, secondary combustion occurred in the kiln stack. Since the combustion of gases was greatly accelerated by contact with hot surfaces, the lime acted as a catalyst, resulting in an unusually perfect combustion.[28]

Furnaces in separately fired kilns were built into the side of the kiln, several feet above the draw hole of the cooler (Figure 6). Heat was produced in furnaces that were separated from the limestone charge. Small kilns had two furnaces, one on each side, while larger kilns had four furnaces, or two per side.[29]

Separately fired kilns were generally hand fired, requiring a skilled and attentive operator. Frequently, the heat tended to rise up the sides of the kiln, producing a core of imperfectly burned material. In some kilns, a central masonry core was built to avoid this problem. Similarly, it was difficult to maintain a continuous high temperature. Placing new fuel on the grate temporarily lowered the temperature of the fire, although these fluctuations could be somewhat reduced by using fireplaces that were so wide that only half of each was fired at a time.[30]

In hand-fired boiler furnaces, it was formerly the practice to supply from four to five cubic feet of combustion space per square foot of grate area. While this was considered adequate for high grade coal, by 1900 it was recognized that low grade fuels required considerably more space.

The principle parts of a coal furnace were the firebox, grate, front support, rear support and bridge wall, and the ashpit (Figure 10).

The firebox was the area above the grate and the combustion chamber – where the fuel and gases were consumed. In some fire doors, the opening was constructed with a cast iron removable arch and jam, such that these parts could be removed and replaced without disturbing the brick work. Yet another design involved the use of a fire brick arch below the jam.[31]

Grates consisted of alternate bars and spaces to support fuel and to admit the necessary air for combustion. The simplest form was called a stationary grate with ordinary straight metal bars

separated by air spaces. These spaces usually constituted between 30-50% of the total grate area. In burning coal, the size of the air space between the grates was mainly determined by the size of the coal, although the space was rarely more that half an inch in height. Grate bars were typically about three feet long and the preferred material was cast iron. Stationary grates required that the firebox be frequently opened in order to work the fire, which in turn resulted in an inrush of cold air, thereby reducing fuel economy and potentially injuring the fire brick lining. While rocking and shaking grates reduced the labour of breaking up clinkers, thereby avoiding the problems of furnace efficiency, they were more expensive to install.[32]

The front support, or dead plate, was the bottom of the door frame extending back to form a shelf for the front support of the grate bars. In some cases, the door frame could extend back a considerable distance to form a dead plate upon which coal could be piled at the time of initial firing. This allowed the coal to assume the character of coke before it was pushed back into the fire.[33]

The rear support, or bridge wall, provided support for the back ends of the grate bars. The wall was usually constructed several inches above the grate bars, using fire brick to provide a bridge wall that increased the draft and prevented fuel from being carried past the grate. It also helped prevent the stone in the stack from falling into the firebox. The flame passages from the firebox into the stack were called eyes.[34]

The depth of the ashpit was dictated by the height of the grate above the floor at which firing could be conveniently accomplished. This height was never more than about 20 inches. Doors were placed on the ashpit in order to regulate draft although when they were closed, the fire would cause the grates to over-heat and deteriorate. Ideally, a pool of water several inches deep, was maintained in the ashpit. The vapour from the pool would serve to protected the grate bars from becoming over-heated.[35] Kilns were usually operated with the ashpit doors closed.[36]

2.2.4.3 Furnace Design: Natural Gas

Gas fired kilns were much easier to manage than those using solid fuel. Since a gas fired furnace contained little fuel at any one time, combustion was regulated quickly and accurately.[37]

In a properly designed gas fired kiln, gas ports were located so as to ensure perfect mixing of gas and air as well as an even distribution of the mixture over the charge. The furnace was designed such that if problems developed, the location of the gas ports and the direction of the gas currents in the furnace could be modified after the furnace had been completed.[38]

Converting a coal fired kiln to gas was not difficult. The necessary installation consisted simply of replacing the fire box with burners. Properly placed gas and air ports in the walls of the kiln ensured that combustion occurred within the kiln chamber itself. Combustion air could be admitted with the gas or drawn in through the cooler.[39]

The effectiveness of a gas fired kiln depended on the gas pressure and air ratio. Mixing air with gas prior to combustion produced a short flame, while post-combustion mixing produced a flame of maximum length but of relatively low temperature. In a well managed kiln, the gas reached the centre of the stone charge. One of the few early references to the use of natural gas in lime kilns dates to 1890, whereby in one operation, gas was reduced to a pressure of three ounces and mixed with air in the kiln. A pressure of three ounces is similar to that used in a modern domestic gas furnace.[40]

2.2.5 *Access Arch and Draw Hole*

All of the lime in a kiln could not be drawn at one time since it was desirable to let it cool within the kiln itself. The lime also functioned to fill the cooler and prevent unburned stone from falling below the level of the active burning zone. The drawing operation consisted of opening a draw door situated in the lower part of the cooler, poking the lime loose with a bar, and allowing it to fall into a barrow or car placed below. This operation was repeated at intervals ranging anywhere from one to eight hours, although it was usually performed every four to six hours.[41]

During the burning process, the stone charge occasionally fused and stuck to either the cooler or the stack lining. Strategically placed poke holes throughout the kiln enabled the operator to insert rods to dislodge the charge (Figures 5 and 7). During the time of drawing, the charge may have fallen down uniformly or it may have adhered to the lining in the region of the eyes, allowing a cavity to form in the cooling zone. After the drawing was finished, the charge was to be knocked down by bars introduced through poke holes in the furnace. This method used less coal and worked well with stone that had a very low quantity of impurities. With less pure stone, sticking could occur at any time. Some operators deliberately brought it about by cooling the kiln slightly, just before drawing.[42]

Endnotes - Section Two

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3. Mills, *Materials of Construction*, 23; *Pit and Quarry Hand Book*, 380; Bowles, *Stone Industries*, 388.

4. Mills, *Materials of Construction*, 23; Ontario, "Limestones of Ontario," 8-9; Toft, "Lime Burning; *Pit and Quarry Hand Book*, 379.

5. Mills, *Materials of Construction*, 23; Ontario, "Limestones of Ontario," 8-9; *Pit and Quarry Hand Book*, 379-380.

6. Mills, *Materials of Construction*, 23, 33, 38, 45; Ontario, "Limestones of Ontario," 8-9; Toft, "Lime Burning"; *Pit and Quarry Hand Book*, 379-380.

7. Mills, *Materials of Construction*, 24-25; *Pit and Quarry Hand Book*, 379.

8. Mills, *Materials of Construction*, 24-25; *Pit and Quarry Hand Book*, 382.

9. *Pit and Quarry Hand Book*, 382; Toft, "Lime Burning."; Ontario, "Limestones of Ontario," 7-10.

10. Ontario, "Limestones of Ontario," 7-10.

11. *Pit and Quarry Hand Book*, 380; Mills, *Materials of Construction*, 26.

12. *Pit and Quarry Hand Book*, 380-381; Heinrich Ries, "Lime and Cement Industries of New York," *Bulletin of the New York State Museum* (8:44, 1901), 662; Chemical Catalogue Company, *Chemical Engineering Catalogue* (1924), 629.

13. Ontario, "Limestones of Ontario," 7; *Pit and Quarry Hand Book*, 380-383; F.T. Havard, *Refractories and Furnaces: Properties, Preparation, and Application of Materials Used in the Construction and Operation of Furnaces*, 206.

14. Ontario, "Limestones of Ontario," 7-8; *Pit and Quarry Hand Book*, 380-383.

15. Havard, *Refractories and Furnaces*, 216-218.

16. Havard, 206; *Pit and Quarry Hand Book*, 380-381.

17. Havard, 206.

18. Havard, 335; *Audel's Engineers and Mechanics Guide* (Vol 6, 1921 ed.), 565.

19. *Pit and Quarry Hand Book*, 381; *Chemical Engineering Catalogue*, 629.

20. Havard, *Refractories and Furnaces*, 216-218.

21. Ries, "Lime and Cement Industries," 662.

22. *Pit and Quarry Hand Book*, 381.

23. International Textbook Co, *Manufacturer of Cement*, 12; Mills, *Materials of Construction*, 27-28.

24. Mills, *Materials of Construction*, 27-28; Ontario, Bureau of Mines, *Annual Report* (1891), 131-132; Ontario, "Limestones of Ontario," 8.

25. Mills, *Materials of Construction*, 27-28; Ontario, "Limestones of Ontario," 8; *Pit and Quarry Hand Book*, 381.

26. Ontario, Bureau of Mines, *Report* (1891), 131; F. Clapp, Canada, *Petroleum and Natural Gas Resources of Canada*, Bulletin #291, 1914.

27. *Chemical Engineering Catalogue*, 629.

28. William Walker, Warren Lewis and William McAdams, *Principles of Chemical Engineering*, 212-214.

29. Ontario, "Limestones of Ontario," 7; Ries, "Lime and Cement Industries," 662.

30. Alfred B. Searle, *Limestone and Its Products, Their Nature, Production and Uses*, 420-421.

31. *Audel's Engineers and Mechanics Guide*, 2-436, 438, 577.

32. *Audel's Engineers and Mechanics Guide*, 2-436, 438, 440-441, 443-445.

33. *Audel's Engineers and Mechanics Guide*, 2-436, 438.

34. *Audel's Engineers and Mechanics Guide*, 2-436, 438; *Pit and Quarry Hand Book*, 381-382.

35. *Audel's Engineers and Mechanics Guide*, 457-458.

36. *Pit and Quarry Hand Book*, 381; Walker, *Principles of Chemical Engineering*, 212.

37. Searle, *Limestone and Its Products*, 420; Walker, *Principles of Chemical Engineering*, 222.

38. Walker, *Principles of Chemical Engineering*, 210-219.

39. Mills, *Materials of Construction*, 27-28; *Pit and Quarry Hand Book*, 381.

40. Ontario, Bureau of Mines, *Report* (1891), 135.

41. Mills, *Materials of Construction*, 29; *Pit and Quarry Hand Book*, 380-381.

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3.0 KILN ONE
by C. Andreae

3.1 General Description

The 1991 excavation revealed that Kiln One was a separately fired continuous kiln constructed of stone (Plate 1; Figures 11 and 12; Historica Research Limited and Archaeological Services Inc. 1992). The kiln was fired from two furnaces, one on the north and one on the south side of the structure. The working area in front of each furnace was protected by roofed chambers that were probably built to shelter workmen, tools or fuel. The roof was intact on the south side but had been removed or had collapsed on the north side. The front (east) and south walls of the kiln were intact but the north wall had partially collapsed (Plate 8).

A small draw arch at the bottom of the kiln was situated in a rock cut. Metal tie rods about $1\frac{1}{2}$ inches in diameter, were used to hold the kiln together during the thermal expansions and contractions resulting from the high heat of operation. One set of the rods was placed parallel to the four faces of the kiln and was held together with loops and bolts. The second set was built into the stone mass of the kiln and placed at a 45° angle to the sides of the kiln.

The exterior walls were constructed from very large stone blocks laid without mortar. About half way up the kiln, the walls began to batter, or taper inwards, very slightly. The top of the stack was not visible due to rubble. The body of the kiln was filled with rubble but this was loosely packed and large voids existed within the fill. The kiln stack was offset by about one foot to the south from the centre line of the kiln structure. The back of the kiln (west side) was built into an earth and rock bank. The overall height of the ruin from the floor of the draw hole to the highest point of the existing kiln stack was 20.3 feet. The body of the kiln was approximately square, with an 18 foot long base.

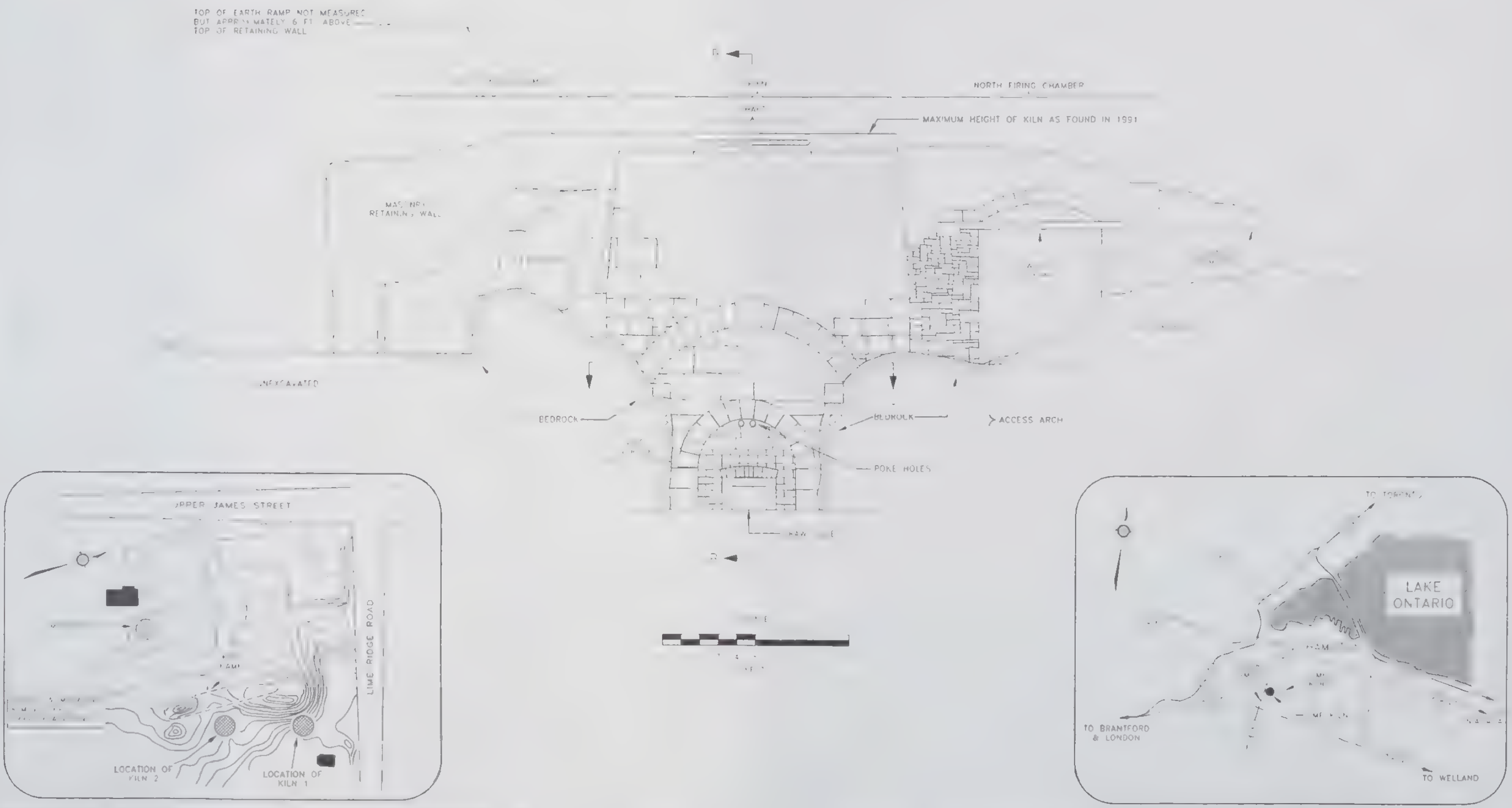
The description of our 1994 excavations are provided below in four components -- Stack, North Furnace, South Furnace, and Access Arch/Draw Hole.

3.2 Stack

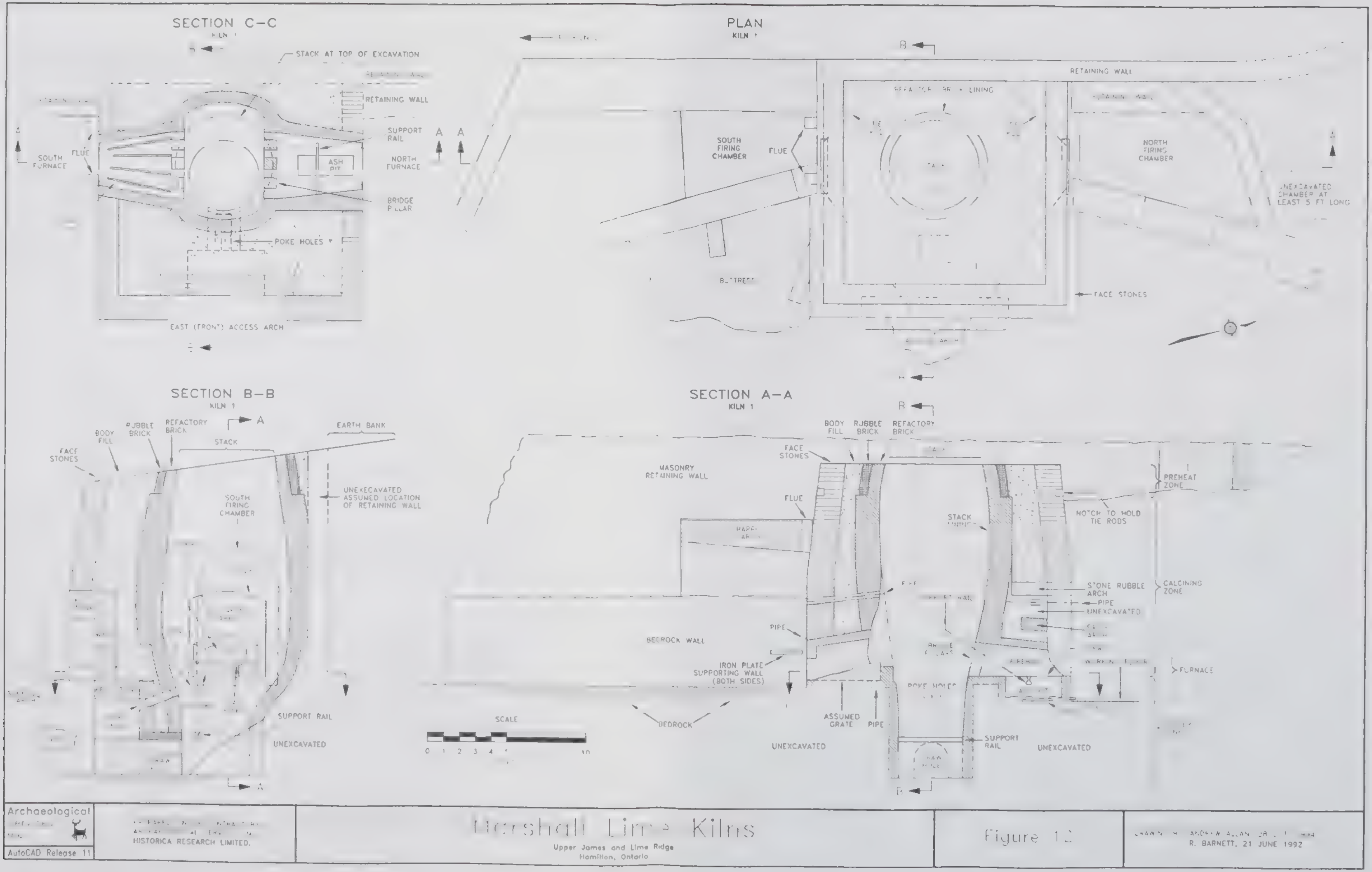
3.2.1 Materials

As a consequence of heat destruction of the refractory brick, no complete blocks were located in the kiln lining. Indeed, almost half of the length of the bricks had been burned away in some areas. Complete bricks found near the top of the kiln suggest that standard refractory sizes were used for different parts of the lining. The blocks at the top of the stack had standard dimensions of $2\frac{1}{2}$ inches by $4\frac{1}{2}$ inches in thickness and width. Assuming that the blocks were nine inches long, their inner faces would have been about 3-$3\frac{1}{4}$ inches wide. A standard block taken from just below the fireboxes had a four inch wide face (Figure 9; Plate 6).

FRONT ELEVATION
KILN 1



Archaeological Services Inc. / AutoCAD Release 11	PREPARED UNDER CONTRACT BY: ARCHAEOLOGICAL SERVICES INC., HISTORICA RESEARCH LIMITED	**Marshall Lime Kilns** Upper James and Lime Ridge Hamilton, Ontario	Figure 11	DRAWING BY: R. BARNETT, 21 JUNE 1992 DRAWING REVISED BY: ANDREW ALLAN, 28 OCT 1994


SECTION C–C
KILN 1
STACK AT TOP OF EXCAVATION
RETAINING WALL
SUPPORT RAIL
SOUTH FURNACE
FLUE
ASH PIT
NORTH FURNACE
BRIDGE PILLAR
POKE HOLES
EAST (FRONT) ACCESS ARCH
PLAN
KILN 1
RETAINING WALL
SOUTH FIRING CHAMBER
FLUE
NORTH FIRING CHAMBER
UNEXCAVATED CHAMBER AT LEAST 5 FT LONG
FACE STONES
SECTION B–B
KILN 1
FACE STONES
BODY FILL
RUBBLE BRICK
REFACTORY BRICK
STACK
EARTH BANK
SOUTH FIRING CHAMBER
UNEXCAVATED ASSUMED LOCATION OF RETAINING WALL
SUPPORT RAIL
UNEXCAVATED
SECTION A–A
KILN 1
BODY FILL
RUBBLE BRICK
REFACTORY BRICK
FACE STONES
MASONRY RETAINING WALL
FLUE
STACK
PREHEAT ZONE
NOTCH TO HOLD TIE RODS
STONE RUBBLE ARCH
PIPE
UNEXCAVATED
CALCINING ZONE
FURNACE
BEDROCK WALL
PIPE
IRON PLATE SUPPORTING WALL (BOTH SIDES)
POKE HOLES
BEDROCK
ASSUMED GRATE
PIPE
SUPPORT RAIL
UNEXCAVATED
UNEXCAVATED
SCALE
0 1 2 3 4 5 10
Archaeological
AutoCAD Release 11
HISTORICA RESEARCH LIMITED.
Marshall Lime Kilns
Upper James and Lime Ridge
Hamilton, Ontario
Figure 12
R. BARNETT, 21 JUNE 1992

The blocks in the top two feet of the kiln were marked with what appears to be "WBS["S" is reversed]TEEL2". Elsewhere the bricks were marked "BUCKEYE". Some blocks had no visible marking.

In general, the bricks appear to be fire clay, although some were composed of material that resembles crushed brick or slag mixed with fire clay. The block that is marked "WBSTEEL" seems to be of this composite material while the "BUCKEYE" bricks seem to be of fire clay.

At the bottom of the draw arch, the area was constructed of common brick. These bricks were red clay and measured approximately 8½ inches long, 3½ inches wide and 2½ inches thick. The frogs measured two inches wide, about two inches long and roughly half an inch deep.

The refractory brick lining was mortared with fire clay, while the common bricks at the draw hole were mortared with lime mortar.

3.2.2 Construction

At the top of the kiln, the front (east), north and south sides of the structure consisted of five layers (Plates 2 and 3):

- Single firebrick lining of stack, mortared and heavily vitrified;
- Layer of mortar approximately 1½-2 inches thick;
- Firebrick scrap, approximately six inches in length, four inches in width and 2½ inches in thickness, laid in mortar;
- Loose rubble (six to eight inches in diameter) about two feet thick, laid without mortar with void; and
- Face stones, generally about 14 inches thick, of kiln exterior.

The rear (west side) of the kiln was similar except that there was only a two foot space between the firebrick lining and the face stones of the retaining wall.

Beginning about two feet below the top of the stack, the firebrick lining was two bricks thick, the inner wall having been constructed of old refractory brick (Plate 4). This seems to be a replacement of the firebrick scrap with higher quality brick, probably to compensate for increased heat in this area.

At about ten feet below the top of the kiln, the general construction features were similar to those at the two foot layer (Plates 6 and 7). On the north/west side, the area between the retaining wall and the stack lining was filled with rubble that included scrap brick and stones, some of which were larger than the six to eight inch stones noted above. The wall behind the large access arch was not bonded to the outer face stones.

At the level of the inner access arch, the refractory brick lining had reverted to a single brick thickness, which continued into the cooler zone (Plate 24).

3.2.3 *Condition of Lining*

The refractory brick lining of the kiln stack had been fused by heat into a solid wall (Plate 4). The refractory brick lining showed varying degrees of wear throughout the kiln. In some places, about half of the lining had been burned away. The brick was generally the longest at the top of the kiln where it would have been relatively cool.

The brick was approximately eight inches deep at the top of the stack and showed little vitrification (Plate 3). While the stack end of the blocks had a rough appearance, indicating only minimal melting, heating marks, resembling soot or smoke stains, penetrated back about 1 to 1½ inches along the brick surface. There was almost no vitrified material but the ends of the bricks appeared to have been abraded by the movement of the stone charge.

At approximately four feet below the top of the kiln, some refractory brick was only 5½ inches deep, indicating that about 3½ inches had burned away. Evidence of vitrified material had penetrated about 2½ inches between the brick joints leaving only three inches to the back of the fire brick. This would imply that melting heat had come within three inches of the back of the brick. At the same four foot level, another section of brick from the same area was seven inches deep but the vitrification had, nevertheless, extended about 2½ inches through the joints (Plate 4).

A block taken from the stack at the top of the draw arch keystone was similar to that noticed at the top. Very little melting had occurred and the block had a light powdery gray appearance. In the hotter parts of the kiln, some of the material was a very dark gray and was mixed with glassy material.

At about five feet below the top, a four foot deep lens of lime was noted in the fill between the refractory lining and the north-east corner of the exterior wall on the north furnace (Plate 5). Some burnt material such as wood and coal was mixed in with this lime. Moreover, there was some evidence on the east wall in this area that a burn-out through the kiln lining had occurred. This was evidenced by an area measuring approximately one foot in depth that was burned back into the core material.

3.2.4 *Stack Profile*

Although not perfectly circular, the stack at the top of kiln measured very close to six feet in diameter (Plate 2). At approximately four feet below the top, the stack became oval. While the north and south walls – those containing the furnaces – were effectively vertical, the east and west walls gradually tapered out to form the oval. At the top of the firebox arch, the stack remained approximately six feet wide on the north-south axis but measured approximately seven feet six inches wide on the east-west axis. An accurate measurement of this area was impossible because so much of the south firebox arch had collapsed.

At the level of the furnace hearths, the stack was almost rectangular. The firebox walls were straight, but the east-west axis was slightly curved (Plate 5). The hearths on both sides of the kiln lay at approximately the same elevation.

The shaft began to bell inward at a pronounced rate at approximately the level of the gas jets in the south furnace (Plate 6).

At the level of the top of the keystone of the inner arch, the north and south walls were vertical and straight (Plate 24). The east and west walls belled slightly inwards and were semi-circular. The stack at the cooler was vertical and approximately four feet two inches in diameter.

3.2.5 Soot Marks

The lining between the blocks on the exterior walls above the fire boxes seem to have been covered with soot. The soot was also apparent inside the rubble fill, at least as far as seven feet below the top (two to three feet above the furnace), along the east wall. Cracks in the side would probably have allowed the smoke to filter through on the east side. The sooty condition inside the rubble fill of the kiln body suggests that the furnace or stack lining must have been sufficiently porous to enable some smoke to penetrate the kiln.

3.3 North Furnace

As a result of the 1991 excavations it was known that the retaining wall butting against the east side of the kiln was a second, thicker wall constructed inside the original retaining wall (Figure 12 and Plate 8). The retaining wall was again observed in 1994.

The frame of the firebox door was separated from the wall by a single layer of brick (Plate 9). The firebox door was in line with the facing stones of the kiln. The working floor in front of the furnace was approximately five feet above the floor of the draw hole. The firebox door had been damaged, presumedly by the Gradall prior to the feature being identified. Most of the structure was *in situ*, but the top of the cast iron jam had been damaged. The door was hinged on the east side. The firebox front consisted of a hearth or base, two sides and a top. The frame was held into the stone work by tie-rods on either side of the door jamb.

The firebox at the firebox door was approximately 18 inches to the springing line of the arch and approximately 20 inches to the crown of the arch. The roof of the firebox at the door was constructed of limestone blocks, rather than refractory brick. On the basis of the whiteness and flaking on the exposed surface, they seem to have been exposed to heat. The rest of the roof was refractory brick.

The grate bars were wrought iron, measuring one inch thick and two inches wide, and were set upon a one-quarter inch gap and slotted under the iron of the firebox door. The bars had been warped six to eight inches due to heat (Plates 10, 11 and 13). The ashpit grates were supported at the north end by an iron bar. The middle was supported by a piece of railway rail. At the

south end, there was a row of fire brick that contained two tie-rods to hold down the grates. The ashpit measured approximately 12 inches wide and three feet long and was filled with a powdery material that appeared to be decayed mortar. The bottom of the pit rested on bedrock approximately 14 inches below the firebox floor.

There appeared to be approximately one foot of hardened lime and approximately one foot of rubble on top of the grates in the firebox. There was a narrow gap of about six inches between the top of the rubble and the roof of the arch. No evidence of gas pipes was found in the firebox.

Four iron pipes were documented on the exterior side of the furnace near the floor level (Plate 10). They entered below the grate level on either side of the ashbox. These pipes were approximately three inches in diameter and extended out approximately nine inches from the face of the furnace. The iron pipes did not appear to enter the kiln stack. Instead, one was excavated through the floor of the hearth such that the refractory block lining was built over its end. The ends under the firebox hearth were blocked with refractory brick.

Above the firebox roof arch lay a five to six inch thick layer of brick rubble (Plate 9). On top of this rubble was a second arch refractory brick. While the purpose of the feature could not be determined, it may either have been the remains of an older and larger furnace, or a relieving arch.

Above this second firebrick arch was another area of brick fill, measuring approximately 20 inches in thickness (Plate 9). Two iron pipes measuring five and four inches in diameter respectively were found within this fill. The larger pipe was centred while the smaller pipe was offset to the east relative to the centre line by approximately 16 inches. A further dry laid stone arch was found about two inches above the pipes and bound in with clay. It seems to have functioned as a relieving arch.

The firebox arch entrance into the stack was supported by three fire brick pillars measuring approximately nine inches square (Plate 14). These pillars were separated from one another by gaps of between six and ten inches.

The crown of the arch on the east side of the kiln is at almost the same height as the arch on the firebox on the south side.

The refractory brick stack lining formed a continuous and smooth transition into the firebox walls (Plate 13). The double row of refractory brick in the stack became multiple rows inside the firebox. The extra brick seems to have been used as filler between the angle formed by the firebox and the kiln body.

An interesting construction feature of the face stone was observed near the firebox door. Bedrock formed the bottom of the kiln in this location and an iron bar had been fit into a hole drilled into the stone (Plates 11 and 12), presumably to anchor the face stones of the kiln structure.

3.4 South Furnace

The front of the furnace and the work floor were completely excavated in 1991 (Plate 15). A large section of the furnace wall appeared to have been rebuilt, using small stones and refractory brick. In places, the bedrock constituted approximately six feet of the wall height on both sides. In 1991, the chamber was found to contain unstratified fill including 20th century construction material. The firing chamber was enclosed by a barrel arch roof in which were two rectangular openings. These appear to have been flues to exhaust heat from the work area, or to help regulate air in the kiln (Plate 16).

Three, four inch diameter sheet metal pipes were located approximately 2½ feet above the crown of the firebox on the exterior wall (Plate 15).

Approximately two feet below these pipes, a horizontal three inch diameter pipe oriented parallel to the kiln face was noted. The east end of this pipe had disintegrated, but the west end extended into the retaining wall. The pipe was noted again in the 1994 excavation (Plates 15 and 17).

The firebox consisted of an iron frame measuring approximately two feet wide and located six to eight inches off the floor of the chamber. The entrance of the south furnace into the stack was in very poor condition. Much of it had collapsed. It appears that the entrance opened into the stack through a tiered arch, however, too much of this feature had been destroyed to determine its nature and extent. It does appear to have been corbelled, with three bricks up and one brick across, and it may well have extended into the stack (Plate 9).

The bases of three pillars, of a similar design to those noted on the north side, were documented (Plate 18). The upper parts of the pillars, however, were not found, either due to failure during operation or deliberate removal to change the character of the furnace. The base of the pillars, which were preserved in a bed of lime, presumably supported an outer arch of the firebox.

The firebox was filled with stone and lumps of limestone mixed with powdered lime, appearing, therefore, to constitute furnace charge that had fallen backwards into the firebox. Four heavy iron pipes were found lying in this bed of lime material, all on the same plane and aligned with the gaps between the pillars. The east pipe was buried in mortar, but its end had been protected by bricks that had been placed over the opening, probably to prevent lime from clogging the jet. The pipes were located approximately 12 inches above the hearth and consisted of either two inch or 2¼ inch inside diameter pipe. It could not be determined whether the brick covering was intact or had fallen into its current position. Given the stacking arrangement of the brick, however, it is likely that this was the original covering. Nevertheless, there was little evidence of heating around the bricks and they showed no heavy covering of lime.

The hearth level was not excavated due to the thick layer of hard lime. Short sections of iron grates were visible at the firebox door and had been noted in 1991. There was no indication of an ashpit opening on the exterior wall.

Two iron pipes were documented within the layer of brick directly below the hearth (Plate 19). The pipe on the eastern most side encased a thinner pipe. This was the only strong evidence recovered during the excavation to indicate that there may have been a gas pipe inside of an air pipe, providing a logical jet. However, the pipes were very low in the kiln, just above the draw arch and there was no indication that these pipes actually extended into the kiln stack. Indeed, these pipes appear to have been built at the same time as the furnace, in that the eastern pipe is directly below the furnace wall. It would be very unlikely that it was inserted after the furnace had been constructed.

Four iron pipes, which extended into the draft box below the grates were found projecting from the furnace wall into the area where the firemen would have worked.

The hearth floor was about 18 inches above the keystone of the draw arch. At this point in the excavation, a very clear section of the furnace was observed. At least four layers of common rather than refractory brick were noted beneath the furnace (Plate 19).

The east side of the furnace was constructed against a ledge of bedrock leaving space for only a single width of refractory brick between the rock and the combustion chamber (Plate 17).

The most definitive evidence of gas combustion was a section of metal pipe removed from below the east side of the furnace (Plate 19). The outer tube had an inside diameter at approximately 3 3/4 inch and was found to contain a three-quarters inch pipe. Several pieces of similar three-quarters inch pipe were found throughout the site and as fill in the kiln stack. A similar pipe configuration was found in the furnace of Kiln Two.

3.5 Access Arch and Draw Hole

The front of the kiln was supported by a large stone arch that rested on bedrock ledges (Plates 1 and 20). A second, smaller arch provided access to the actual draw hole (Plate 21). While the access arch seems to have been built through a rock cut, the draw hole was built upon a brick floor. The draw hole was quite small and consisted of an iron frame. The front wall of the draw hole consisted of soft red brick up to approximately four feet six inches above the base of the draw hole. Above that height were found three layers of stone disappearing into the arch.

In 1991, a large void was noted in the rock on the south side of the access arch. In 1994, it was noted that the lower two feet of the hole had been filled with a 20 inch high stone retaining wall, behind which was earth fill. Although a smaller similar type of void was observed in the rock on the north side of the access arch in 1991, there was no opportunity to further explore these features in 1994.

Two heavy iron pipes, measuring 4½ inches and five inches in diameter respectively were noted immediately below the keystone of the draw arch (Plate 23). These pipes projected directly into the kiln stack and were apparently poke holes. The five inch pipe was approximately 10½ inches long and was cleanly cut at both ends. The four inch diameter pipe was approximately 13½ inches long but had been roughly cut or broken at each end.

The approximately ten foot difference in ground level between the furnace and floor of the draw hole may represent the face of the former west quarry. Indeed, the kiln was found to be resting on bedrock as sheer rock walls, about six feet high, had been incorporated into parts of the retaining walls. Once the quarry had been abandoned, it would appear that the two kilns were constructed, incorporating the quarry face in their structure.

4.0 KILN TWO

by C. Andreae

4.1 General Description

Kiln Two was also a separately fired continuous kiln with two furnaces and one draw hole (Plate 25; Figure 13). Although functionally similar to Kiln One, it had significantly different architectural characteristics. The most visually prominent feature of this kiln was the use of buttresses to support the front of the structure. The kiln stack is almost square, but the buttresses flare out to produce a continuously curving wall on the front.

Bedrock was not incorporated into the design of Kiln Two as it had been in Kiln One. In fact, apart from one outcropping, which may be a wall, there does not seem to be any bedrock in the vicinity of Kiln Two.

The exterior wall blocks of Kiln Two are generally smaller and more roughly fitted than was the case at Kiln One. Very little dressing seems to have occurred to the blocks and they are laid in a virtually random pattern.

4.2 Shaft

During the 1994 excavations, the stack was exposed to a depth of approximately three feet (Plate 26). The most complete section of lining was on the east side. Although the inner layer of refractory brick was intact to the top of the excavation, the outer stack lining was only apparent at a depth of two feet. The lining on the west side had disintegrated such that only a rough brick wall of scrap remained. The area between the refractory brick and exterior face wall was filled with small stones, sand and clay.

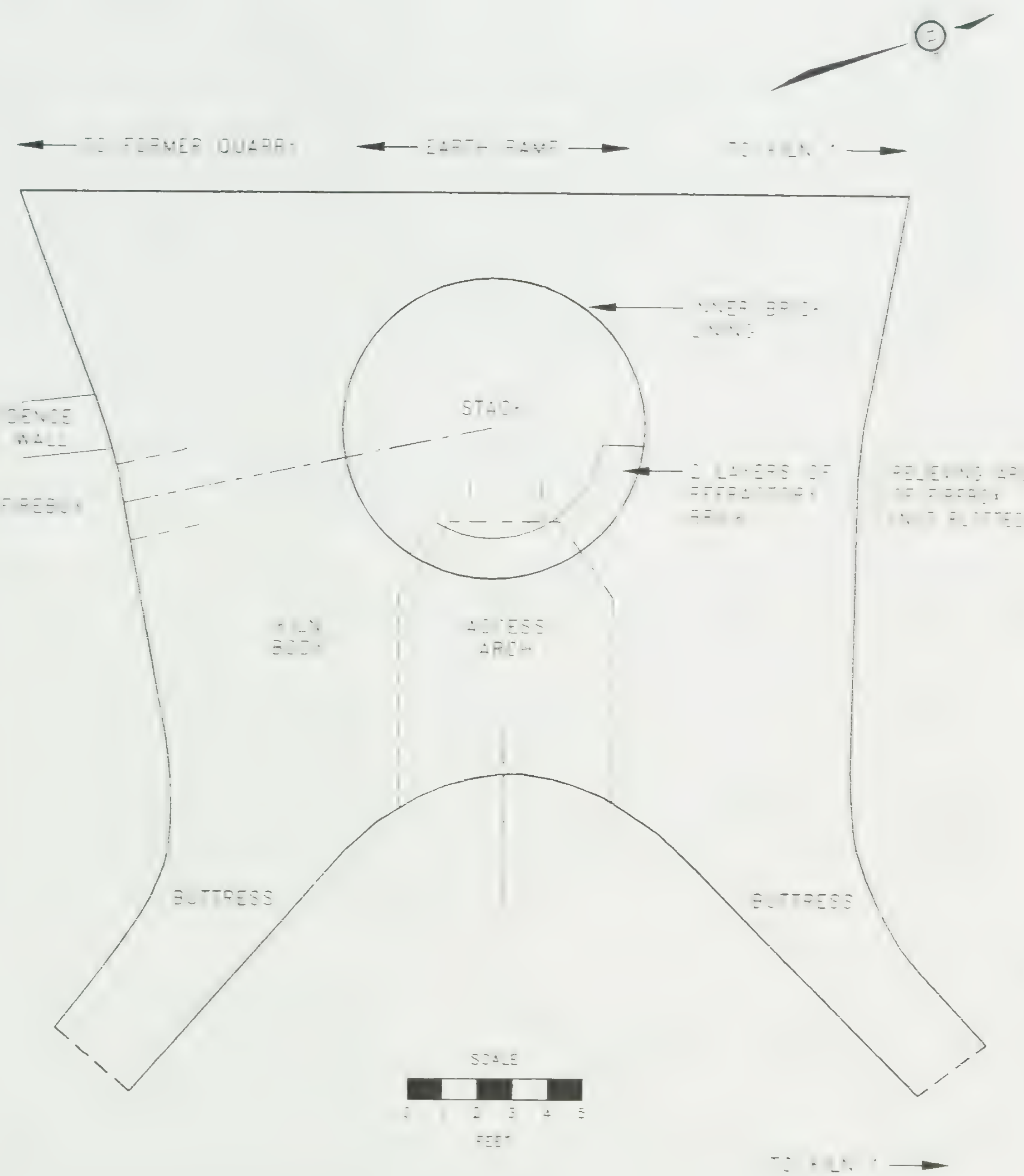
The fill inside of the stack, consisting of brick rubble and only the occasional small stone, was much cleaner than that of Kiln One.

The stack lining was in poor condition. On the northeast corner, the stack seemed to be comprised of one ring of refractory brick set inside a separate outer ring, at a later date, creating a narrower kiln diameter (Plate 27).

4.3 North Furnace

While a small portion of the brick arch and the stone relieving arch of the furnace were exposed, no further investigations were undertaken.

KILN 2 - PLAN AT TOP OF KILN



Archceological Services Inc.	Marshall Lime Kilns Upper James and Lime Ridge Hamilton, Ontario	DRAWING BY: ANDREW ALLAN 26 OCT 1994
AutoCAD Release 11	Figure 13	PREPARED UNDER CONTRACT BY ARCHAEOLOGICAL SERVICES INC. HISTORICA RESEARCH LIMITED

4.4 South Furnace

Upon excavation, it was found that the firebox door still remained on its hinges and that the area had been filled with the door in an open position (Plates 28 and 29). Six 2½-inch diameter pipes, four of which encased three-quarters inch gas pipes, projected out of the firebox. These lay in a flat line along the bottom of the firebox. One pipe from the centre of the air pipes was removed and found to have projected about seven feet, ten inches into the kiln. The three on the east side were displaced sideways – probably during the excavation by the Gradall. A vertical, highly corroded, 2½ inch pipe adjacent to another three-quarters inch pipe was also noted on the east side of the furnace. Yet another buried pipe, about 1½ inches in diameter was found to the west of the furnace door. Directly above and to the west of the furnace was a another five inch diameter pipe that encased a three-quarters inch gas pipe. Above this pipe were three more aligned five inch pipes.

The work floor of the kiln was not excavated. The furnace appears to have had an ashbox that had been encased with brick. The firebox was filled with earth and there was no indication of the lime filling that had been noted in Kiln One.

The wall had a relieving arch built into the masonry, probably to relieve the stress in the wall above the furnace. Three more five inch diameter pipes were situated around the outer edge of the relieving arch. These pipes showed no indication of having had gas jets.

An astonishing feature of this kiln, therefore, compared to Kiln One, was the number of gas fittings that were still extant. While the fittings were largely removed in Kiln One, all of the fittings seem to be intact in this case. The gas manifold was likely attached to the individual gas pipes, but seems to have been caught in the Gradall bucket and separated during the excavation. The manifold had an inside diameter of about 1¼ inch. It branched off a heavy cast iron pipe with approximately 1½ inches inside diameter. The presence of a single valve stem suggests that there was only one set of controls for the burners.

4.5 Access Arch and Draw Hole

The access arch was much larger and more simply constructed than that of Kiln One (Plate 30). It extended about five feet into the kiln.

Considerable quantities of garbage had accumulated in the fill around the draw arch. Some of this material was of fairly recent origin, e.g. a Coke can with a zip tab and a TV dinner tray. About four feet of hard lime material filled part of the opening into the arch. It appears that this material was dumped after the kiln had been abandoned.

The walls of the working space was mortared together with a brownish mortar that had come loose in many places and the stones in the arch appear to have been placed in an irregular fashion.

The floor of the draw holes seems to have rested on bedrock. The draw hole was a cast iron frame and the opening was about six inches above the floor (Plate 31). The working area was eight feet high to the top of the arch and six feet across. The face of the access arch tapered inwards to the draw hole. Part of this arch was supported by a rail just above the draw hole, above which was a five inch diameter pipe. Above that was a second five inch pipe at the beginning of the taper. Above this second, five inch pipe were five poke holes on two levels, all of which tapered slightly upwards. The access arch was free standing from the stack wall. Evidence of hinges on the draw arch was still visible but the door itself was not present. There was a layer of lime or ash on the south side but, in general, the work area was filled with recent garbage and the draw hole was filled with earth.

5.0 ANALYSIS

by C. Andreae

5.1 Kiln One

5.1.1 Stack

The kiln stack was offset by approximately one foot to the south from the centre line of the kiln structure, suggesting that one side of the kiln had been rebuilt. On the other hand, there was no evidence of the front of the kiln having been extended. While no certain explanation could be found for this offset, it was reflected in a deeper furnace on the north side.

The overall height of the ruin from the floor of the draw hole to the highest point of the existing stack was 20.3 feet. Based on a ca. 1900 kiln height of 30-40 feet, about 10-20 feet had been removed from the top of the kiln during its initial demolition. The remains of the earth ramp suggest that the kiln may have stood no more than 28-30 feet in height.

No remains of a hopper were encountered during the investigations. The only surviving feature associated with such a structure was the vestige of the earth ramp that enabled wagons to carry stone from the quarry to the top of the kiln. It is known that as late as 1920 limestone was hauled to the kilns by cart from quarries on the property.[1]

It appears that the lowest portion of the preheat zone remained extant, as is suggested by the single layer of refractory brick and the evidence of abrasion, rather than vitrification, on the refractory block at the top of the excavation.

The calcining zone was found in a relatively complete state along with its two furnaces. The zone was identified by the double layer of refractory brick. The cooling zone was similarly complete.

No analysis was conducted on the bricks used in this kiln but from visual inspection they appear to be fire clay.

The kiln stack had been filled with rubble rather than any type of limestone charge, suggesting that the operation was closed in an orderly manner and that any furnace charge was removed before the kiln was abandoned and the stack filled.

It is impossible to comment on the state of the stack lining. No documentation that describes the characteristics of the lining in an operating kiln could be located. In some places, near the hottest part of the kiln, the lining was very thin. Whether this represents a rapid burning of the lining or the effects of several years of use is not known.

A large body of lime, mixed with wood and coal was found at a depth of five feet from the top of the kiln, in the fill between the refractory brick lining and the north-east corner of the exterior wall. The stack lining in this area had been burned through to a depth of about one foot into the kiln body. It may be that this lime mixture had been used to repair the damage. A stone faced

kiln was probably a very forgiving structure and a burn through in the lining, may not have constituted the catastrophic situation it would have represented had the kiln been a steel structure typical of later 20th century operations.

5.1.2 Furnaces

The two furnaces were the most intriguing components of the excavation as their condition raised as many questions as answers.

The grates and ashpits of the furnaces indicate that the kiln had originally burned wood or coal. At some later date, however, they were converted to natural gas. In 1907, the Marshall kilns were described as burning coal, wood and gas. Kiln One could not have burned coal or wood at the time of closure. Both fireboxes were filled with a kiln charge of limestone that seems to have fallen in during operation rather than after closure. The material had completely covered the grate bars. The ashpits of both fire boxes had been bricked in and were unusable. Under these conditions it would have been impossible to burn solid fuel, suggesting that at the time of abandonment, the kiln could only have burned natural gas.

The north furnace contained a stationary grate made of wrought iron. As noted in technical literature, this type of design was liable to warping and the grates were indeed warped. It would seem, therefore, that such simple grates had been installed to burn wood, rather than coal.

The function of the pipes located above and below both furnaces could not be determined. The four iron pipes below the north furnace that started on the working floor, did not seem to project into the stack. Conversely, a pipe on the south furnace was identified as having perhaps extended into the stack, yet it was not noted on the working floor. This pipe also contained a small diameter inner pipe that is assumed to have transported gas. The fact that these pipes were below the firebox hearth, however, suggests that they may have been used to provide steam or a draught into the kiln. It could not be determined if they were associated with the wood/coal or natural gas phase of the kiln.

The stack entrance from the north furnace contained three intact fire brick pillars situated approximately six inches apart. It is speculated that the pillars acted as walls to prevent stones in the kiln charge from falling back into the fireboxes. Although the size of stone used in the Marshall kilns is unknown, ten inch stone was considered to be optimum.

The three pillars of the south furnace seem to have been removed at some time during the operation of the kiln. The pillars were not required structurally for such a small arch. During the excavation, they were found to be covered with lime material, indicating that the kiln remained in use after their demolition. The collapsed section of furnace lining above the furnace seems to indicate that the design of the firebox opening into the stack must have been different than on the north furnace.

By the early 20th century, gas fired kilns were recommended because combustion could be controlled quickly and accurately. Yet, as late as 1915, some authorities stated that the use of gas (coal gas in this case) had "largely been confined to larger and more modern plants".[2] Given the availability of local, cheap natural gas, the Marshalls likely installed gas for economic reasons, rather than as an attempt to be on the vanguard of a new technology.

No distribution gas pipes were noted in association with the kiln. Typically such pipes were laid on the surface and it would not be surprising if they were removed at an early date.[3]

The type of fuel utilized did not affect the superficial shape of a kiln. In fact, as in the case of the Marshall Kiln One, the same kiln could be converted from solid fuel to gas by simply laying burner pipes in the firebox.[4]

5.1.3 *Fill Material*

Some of the Marshall kilns were demolished in the Depression as a relief measure and to enable the widening of Limeridge Road. Further demolition occurred in the 1950s-60s due to the safety hazard presented by the ruins. Mr. Bauerman, a nearby resident, remembered that a bulldozer and dump trucks had been used in the 1940s-50s to partially destroy and fill the existing site.[5] A 1950s filling of the stack was substantiated by the recovery of disposable ball point pens in the fill at a depth of about four feet below the top of the kiln.

5.1.4 *Date of Kiln*

Neither the 1991 nor the 1994 excavation could determine the precise dates of the kiln's operation. Certainly the changes to the furnaces and signs of wear within the kiln lining attest to a considerable period of use.

5.1.5 *Kiln Size*

The capacity of Kiln One could not be determined. While it is known that, in 1907, all of the Marshall kilns were producing about 100,000 bushels of lime per year and were one of the largest 18 manufacturers in Ontario,[6] this kiln seems small for such a large industrial operation. The draw arch seemed very small and inconvenient as in well-designed kilns, a wagon could be wheeled directly under the discharge. In this case, it had to be raked out and shovelled into wagons.

5.1.6 *Sophistication of the Kiln*

By the late 19th century, technical literature concerning burning lime through the use of natural gas was available. The unidentified functions of the pipes below and above the furnaces suggest

that some changes, not noted in the literature, were necessary in this kiln. The rebuilding suggests that the Marshalls were aware of at least some of these difficulties.

5.2 Kiln Two

The use of buttress walls and smaller facing stones suggest that this kiln was built at a different time than Kiln One. As it was located closer to the quarry, it may very well have been the earlier of the two structures. The less sophisticated construction seems to support this hypothesis.

As noted in the report of the 1991 excavations, the commonly reproduced photograph of the Marshall lime kilns was not Kiln One.[7] While it appears to have been closer in style to the second kiln, it may not have been on this property, given the high bank behind the kiln and the large mass shown in the photograph.

Endnotes - Section Five

1. Ontario, Bureau of Mines, *Annual Report* (1921), 147.

2. Adelbert Mills, *Materials of Construction: Their Manufacture, Properties and Uses*, 27-28; William Walker, Warren Lewis and William McAdams, *Principles of Chemical Engineering*, 222.

3. Ontario, Bureau of Mines, *Report* (1891), 134; F. Clapp, Canada, *Petroleum and Natural Gas Resources of Canada*, Bulletin #291, 1914.

4. Chemical Catalogue Company, *Chemical Engineering Catalogue* (1924), 629.

5. See Archaeological Services/Historica Research, "Archaeological Investigation of the Marshall Lime Kilns," June 1992; also Mabel Burkholder, "The Lime Kilns of Barton," *Hamilton Spectator* (Nov 24, 1951).

6. Canada, *Report on the Mining and Metallurgical Industries of Canada, 1907-1908* Bulletin #24, 1908; Ontario, "Limestones of Ontario," 8; *Chemical Engineering Catalogue* (1924), 629.

7. See, for example Mabel Burkholder, *Barton on the Mountain*, 24.

6.0 RECOMMENDATIONS

by C. Andreae and R. Williamson

6.1 Kiln One

No further work is required.

6.2 Kiln Two

No further work is required.

6.3 Public Access to Information

Copies of this report should be deposited in public libraries and made available to McMaster University and the Hamilton Historical Board. It is also recommended that a document summarizing this work be prepared for commercial publication and distribution by the Region.

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Historica Research and Archaeological Services Inc.
1992 Archaeological Investigation of the Marshall Lime Kilns, 1121 Upper James Street, City of Hamilton. On file with the Regional Municipality of Hamilton-Wentworth.

Plate 1: Kiln One
Front, east side of the kiln, showing maximum height of the kiln as found and the access arch and draw hole, Nov. 25, 1991. Bedrock outcropping is visible just to the left of the range rod.

Plate 2: Kiln One - Stack
Looking down on the kiln at the top of the structure as found, June 29, 1994. The break in the lining at the lower left was made to remove fill from inside of the stack. Retaining wall (west side) is on the right.

Plate 3: Kiln One - Stack
Retaining wall, fill in body of the kiln and refractory brick lining at the top, June 28, 1994. This shows the lining, mortar layer and rubble fill found near the top of the excavation. Note also the porosity of the body fill as demonstrated by the dark hole near the middle of the photograph, adjacent to the retaining wall.

Plate 4: Kiln One - Stack

Kiln stack looking south, June 28, 1994. While the retaining wall holding back the earth bank is on the right, a small portion of the facing blocks on the north kiln wall are visible in the lower left. The double layer of refractory brick lining can be seen on the right. First quality brick lines the stack and was backed by second quality brick.

Plate 5: Kiln One - Stack
Burn-out in refractory brick lining at the upper right of the photo, July 4, 1994. A small area adjacent to the south furnace (on right) contained tunnels of vitrified material extending about a foot into the body of the kiln. The large lime deposit in the kiln body was located behind the range rod.

Plate 6: Kiln One - Stack
Stack lining on the east (front) of the stack showing the profile of the kiln - the range rod is vertical - at the level of the firebox, July 5, 1994. The hearth floor of the north firebox is just visible at the bottom of the photo and the south furnace is the dark hole at the right. The refractory lining bricks are almost the full thickness beneath the hearth level and have been almost completely burned away near the top. The burn-out [Plate 5] occurred in this vicinity.

Plate 7: Kiln One - Stack
Looking down onto the kiln, July 7, 1994. Stack, on left, across the stack lining, body fill and key stone and arch of the lower access arch into the working area, on right, in front of the draw hole (not visible). The keystone is the large block below the range rod and disappearing into the kiln body.

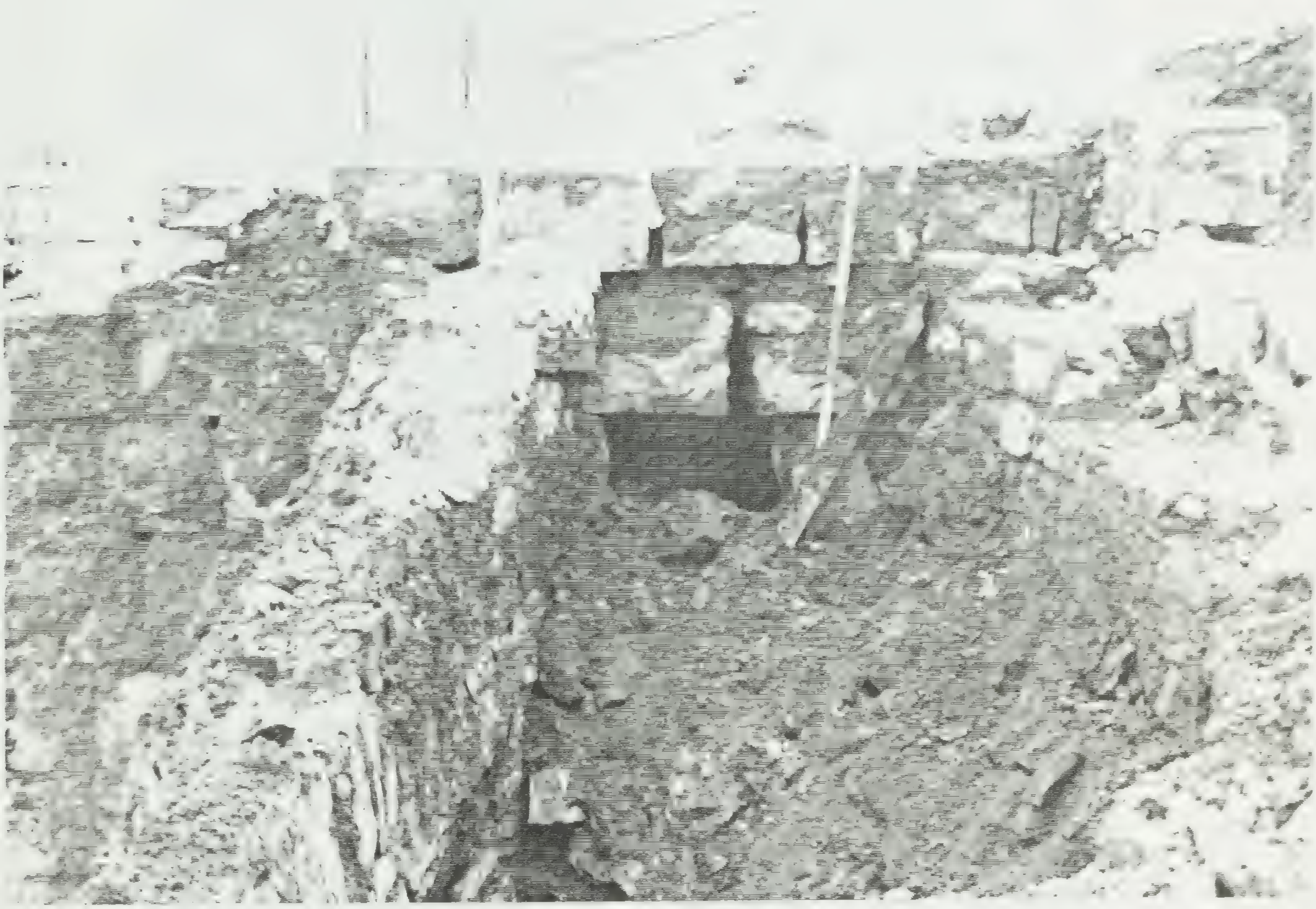

Plate 8: Kiln One - North Furnace
North kiln wall above the firing chamber showing poor condition of the face stones, Nov. 25, 1991. The retaining wall of the north firing chamber in on the right, the exterior wall of the chamber is on the left.

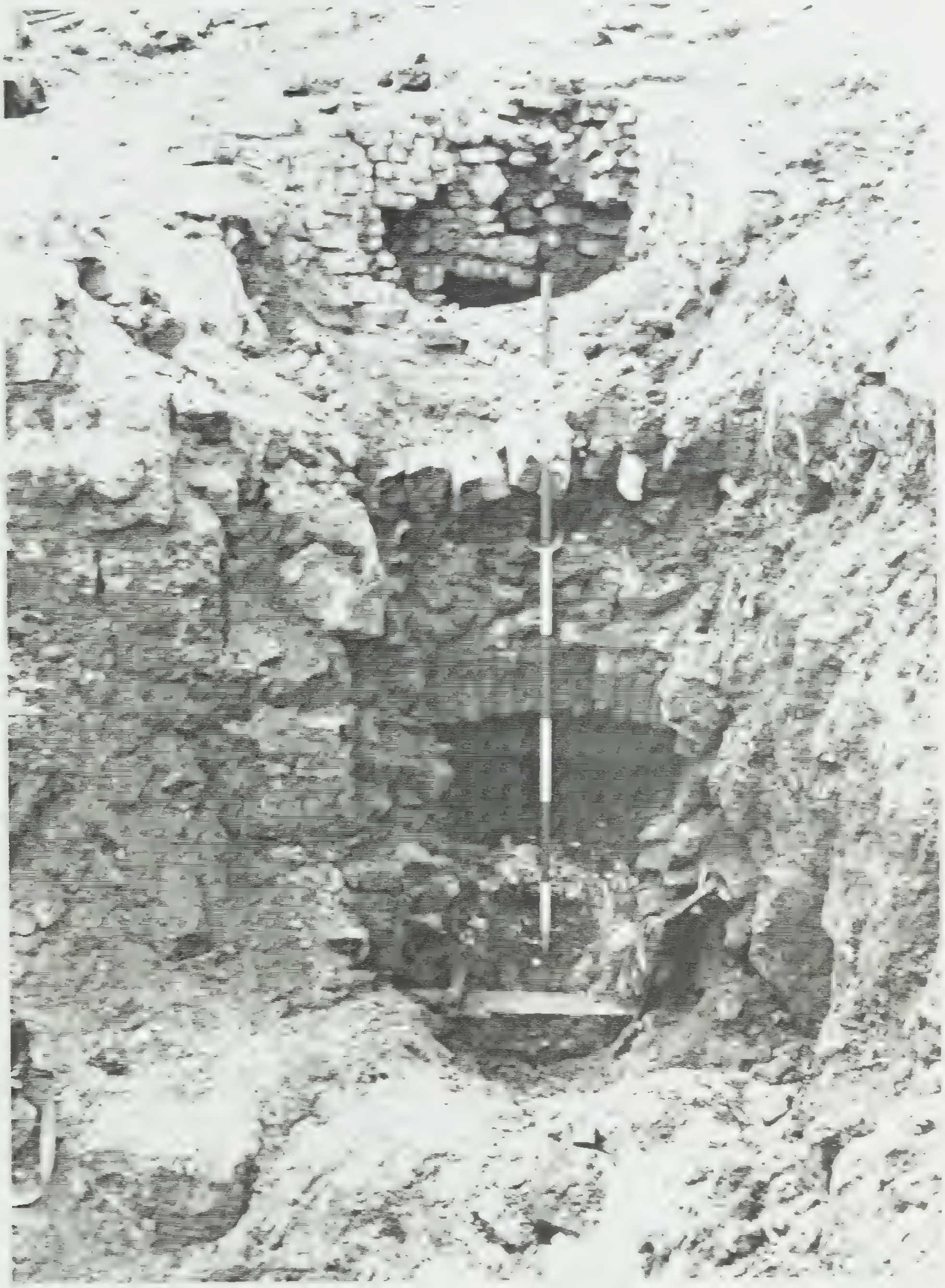

Plate 9: Kiln One - North Furnace

North furnace prior to removal of the arch and stack lining, June 30, 1994. The block held by the iron pin [Plates 11, 12] is immediately to the left of the furnace. The range rod is resting on the iron base of the firebox door and one of the jambs is at an angle to the right of the rod. The actual roof of the firebox is the dark, inner brick lining. The second arch abuts the range rod. The brick fill containing the pipes - one is directly behind the range rod - sits on top of the brick arch. The stone relieving arch is near the top of the range rod. The kiln stack is in the rear and the poor condition of the lining above the south furnace is visible.

Plate 10: Kiln One - North Furnace
Firebox entrance after excavation of the ashbox and replacement of the firebox grates, July 6, 1994. Notice the warp in the grate bars. The pipes of unknown function lie at the work floor level in the front of the kiln. The mouth of the south furnace is just visible at the top of the plate.

Plate 11: Kiln One - North Furnace
Looking down on the firebox after excavation of the ashpit and replacement of the grate bars, July 6, 1994. Photo taken from on top of the retaining wall on the west side with the front of the firebox on the left and the stack on the right. Note the V-shape of the firebox. The parallel rows of brick above the grates was fill between the furnace and the bedrock. The iron pin [Plate 12] is visible at upper left. The pillars in Plate 14 were removed during the excavation of the hearth. The distance between the ashbox and stack lining provided a bridge area.

Plate 12: Kiln One - North Furnace
Wrought iron pin inserted into the drill hole in the bedrock to hold the exterior face blocks of the kiln, July 6, 1994. Located on the left (east) side of the north firebox door.

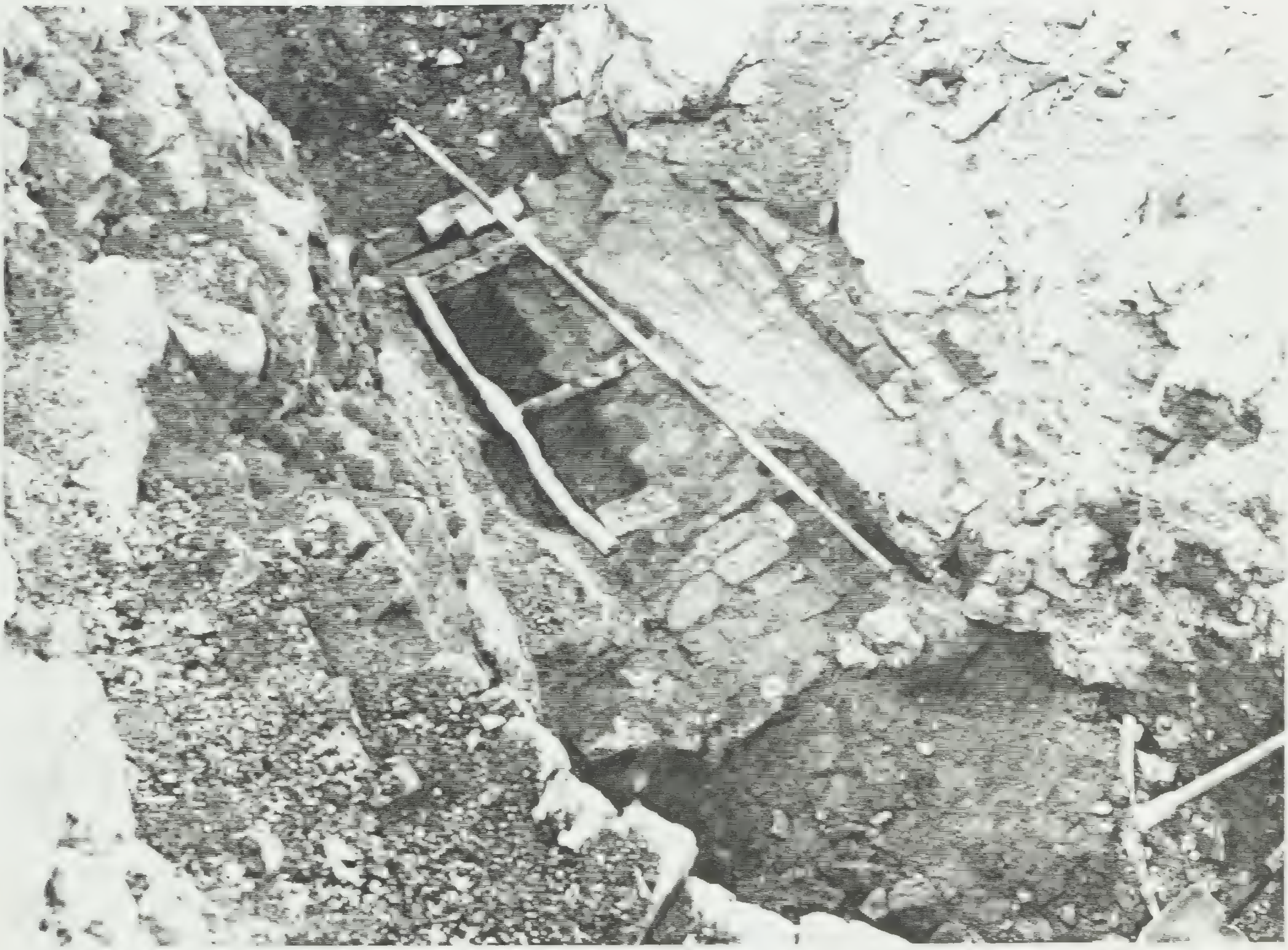

Plate 13: Kiln One - North Furnace
North furnace after excavation of the ashpit, July 6, 1994. Kiln stack at bottom. One metal grate has been replaced over the ashbox. The pillars at the mouth of the furnace [Plate 14] have been removed.

Plate 14: Kiln One - North Furnace
Looking from the stack towards the pillars of the north furnace, July 4, 1994. Lower part of the furnace is still unexcavated.

Plate 15: Kiln One - South Furnace
The south furnace entrance showing the brick arch, three air pipes or poke holes and the Horizontal metal pipe just above the firebox door. Nov. 25, 1991.

Plate 16: Kiln One - South Furnace
Flues on top of the south firing chamber, Nov. 20, 1991.

Plate 17: Kiln One - South Furnace
South furnace showing the brick arch at the front, July 7, 1994. Note the change in the brick arch construction. Bedrock is on the right. The top of the firebox door and the horizontal metal pipe are just visible near the middle of the plate. Straw was placed in front of the furnace following the 1991 excavation.

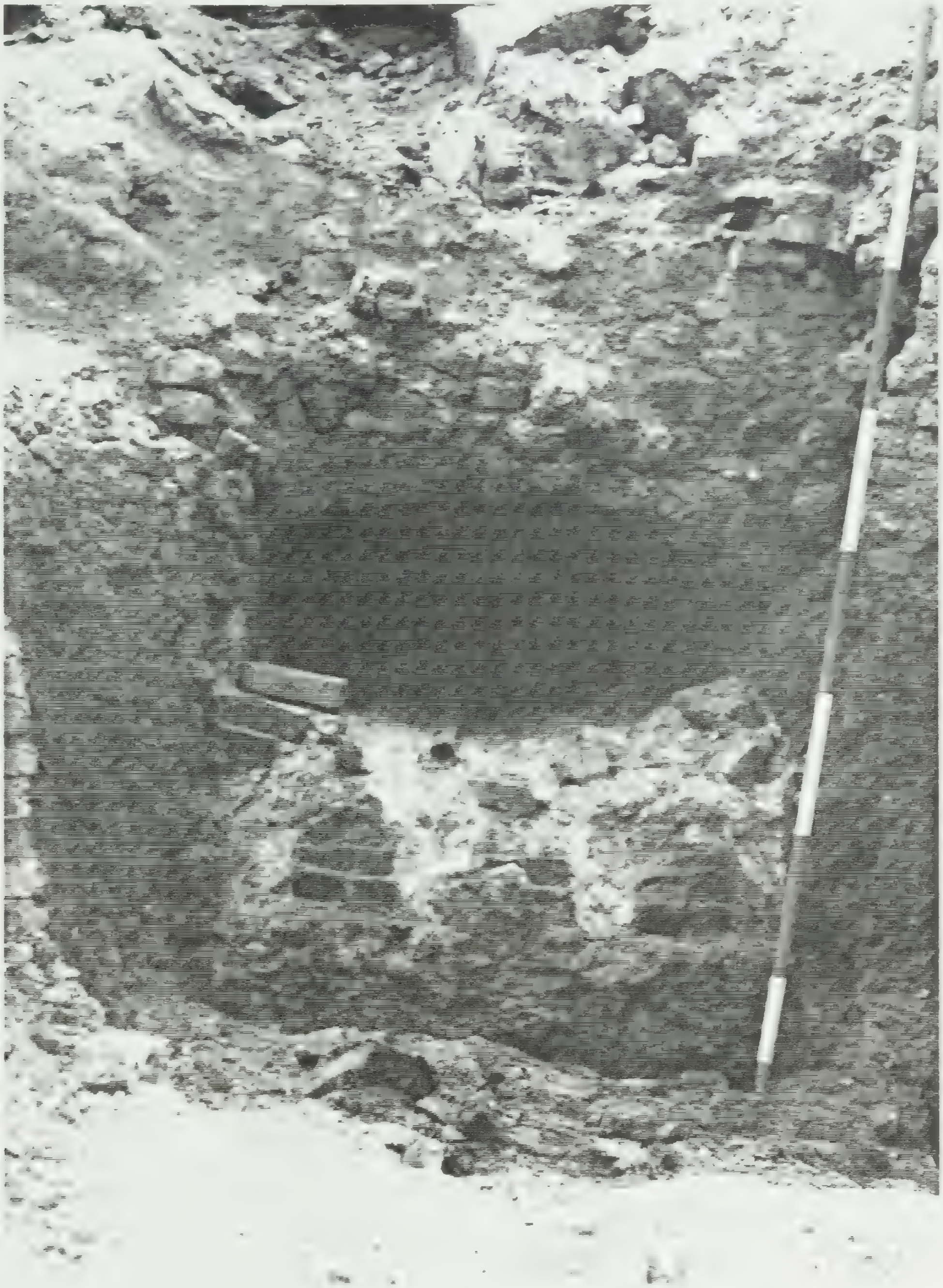

Plate 18: Kiln One - South Furnace
South furnace showing the bases of pillars covered with limestone, July 5, 1994. One gas pipe is visible as is one air pipe to the left, near the top of the range rod. The poor condition of the entrance of the firebox into the stack can be seen by the distance back from the range rock marking the location of the stack. The stack was a straight wall at the mouth of the furnace.

Plate 19: Kiln One - South Furnace
South furnace looking in from the stack, July 8, 1994. The stack lining began at approximately the location of the range rod. Assumed burner pipe is in front of the trowel handle in the lower left of the plate. A second pipe is between the trowel and range rod. Materia! above the brick at the bottom of the fire is limestone that has fallen into the firebox.

Plate 20: Kiln One - Access Arch/Draw Hole
Access arch and excavation of the draw hole prior to the removal of the arch, July 5, 1994. The setting of the outer arch into the bed rock can be seen.

Plate 21: Kiln One - Access Arch/Draw Hole
Draw hole and inner access arch showing three rows of stone block on top of the brick wall surrounding the draw hole, July 5, 1994.

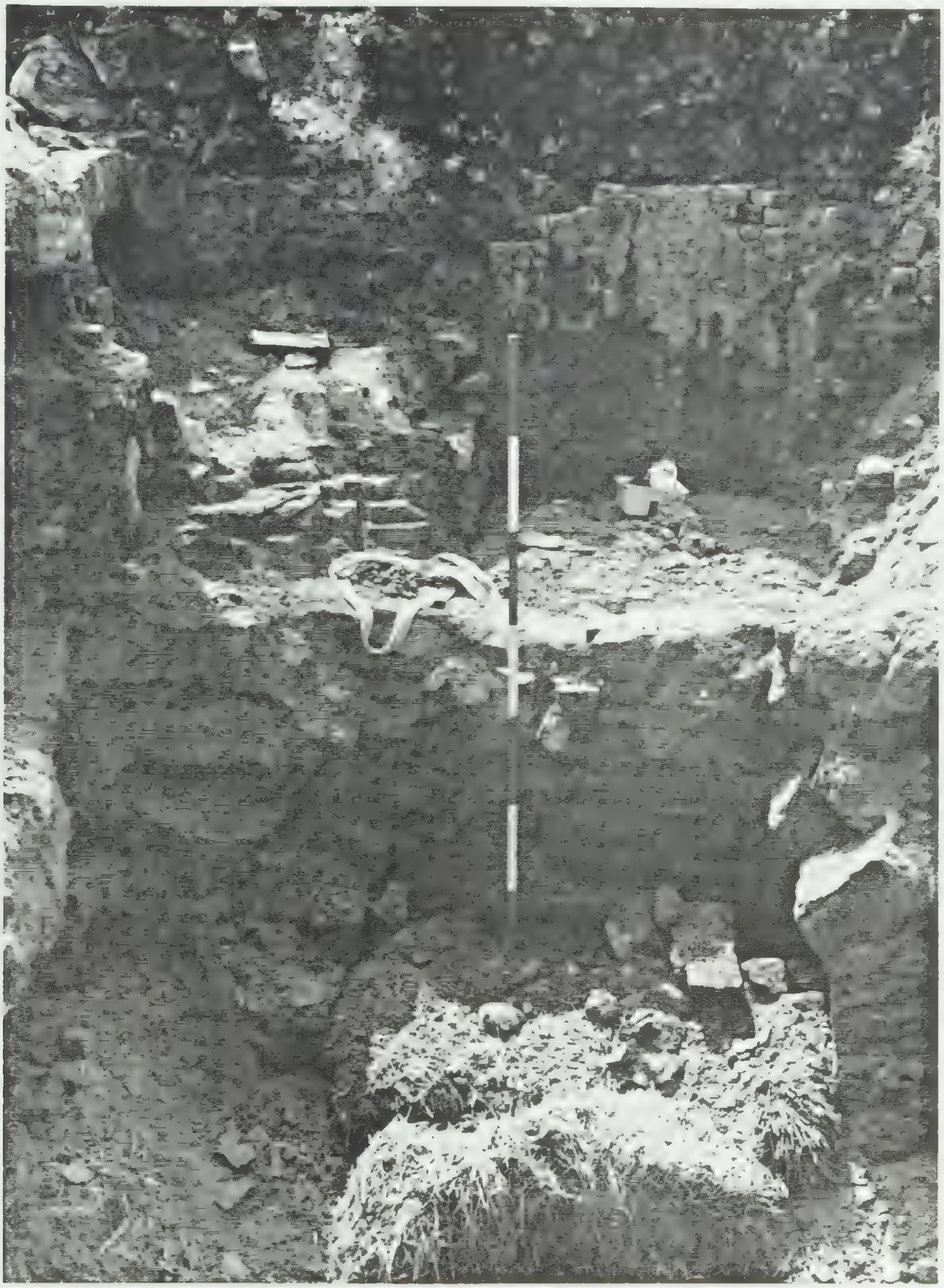

Plate 22: Kiln One - Access Arch/Draw Hole
Access arch after removal of the inner arch, July 8, 1994. The south furnace is on the left; stack lining rises above the range rod in the centre. The narrowness of the stack lining between the front of the kiln and the stack can be seen adjacent to the range rod.

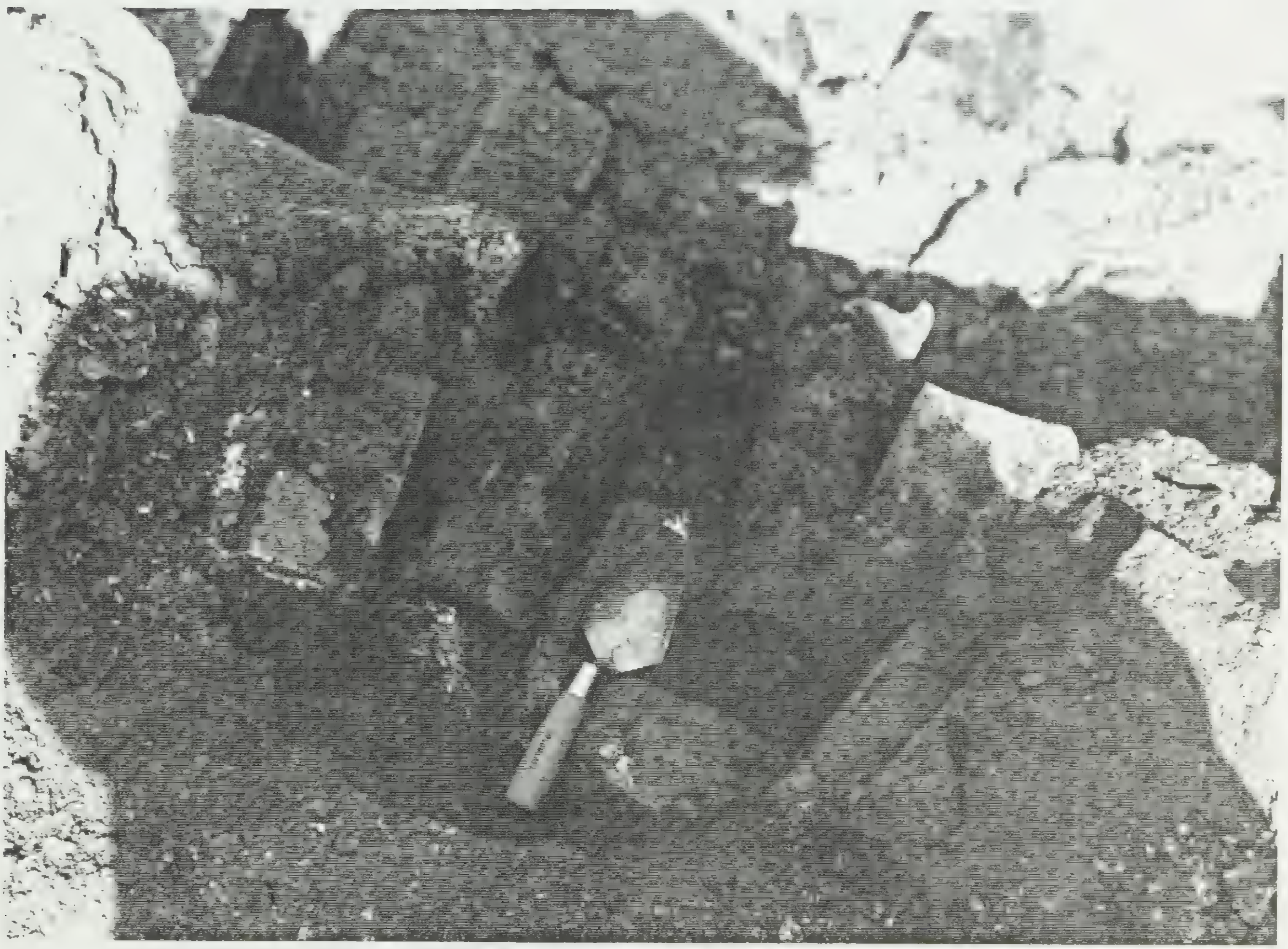

Plate 23: Kiln One - Access Arch/Draw Hole
Poke hole pipes directly above the draw hole, July 8, 1994. The cooler zone of the stack is at the end of the trowel handle. The brick represents the refractory lining of the cooler and the access arch wall runs diagonally across the top of the plate.

Plate 24: Kiln One - Cooler Zone
Cooler zone of the kiln, July 8, 1994. The white area at the upper left of the photo is lime inside the south furnace. The vertical walls of the cooler, beneath the furnace are just left of the archaeologist. A rail just above the draw hole can be seen as a dark straight line in the fill below and left of the shovel. The straight wall of the inner access arch can be seen as an **L**-shape at the lower left. This was the maximum extent of excavation in this area of the kiln.

Plate 25: Kiln Two
Photomontage of the kiln lining generally south with the access arch on the left, retaining wall on the right and a small portion of the stone relieving arch of the north furnace just visible adjacent to the fill in the lower middle of the photo, July 12, 1994.

Plate 26: Kiln Two
Looking south across the stack showing the inner and outer layer of the refractory brick, July 11, 1994.

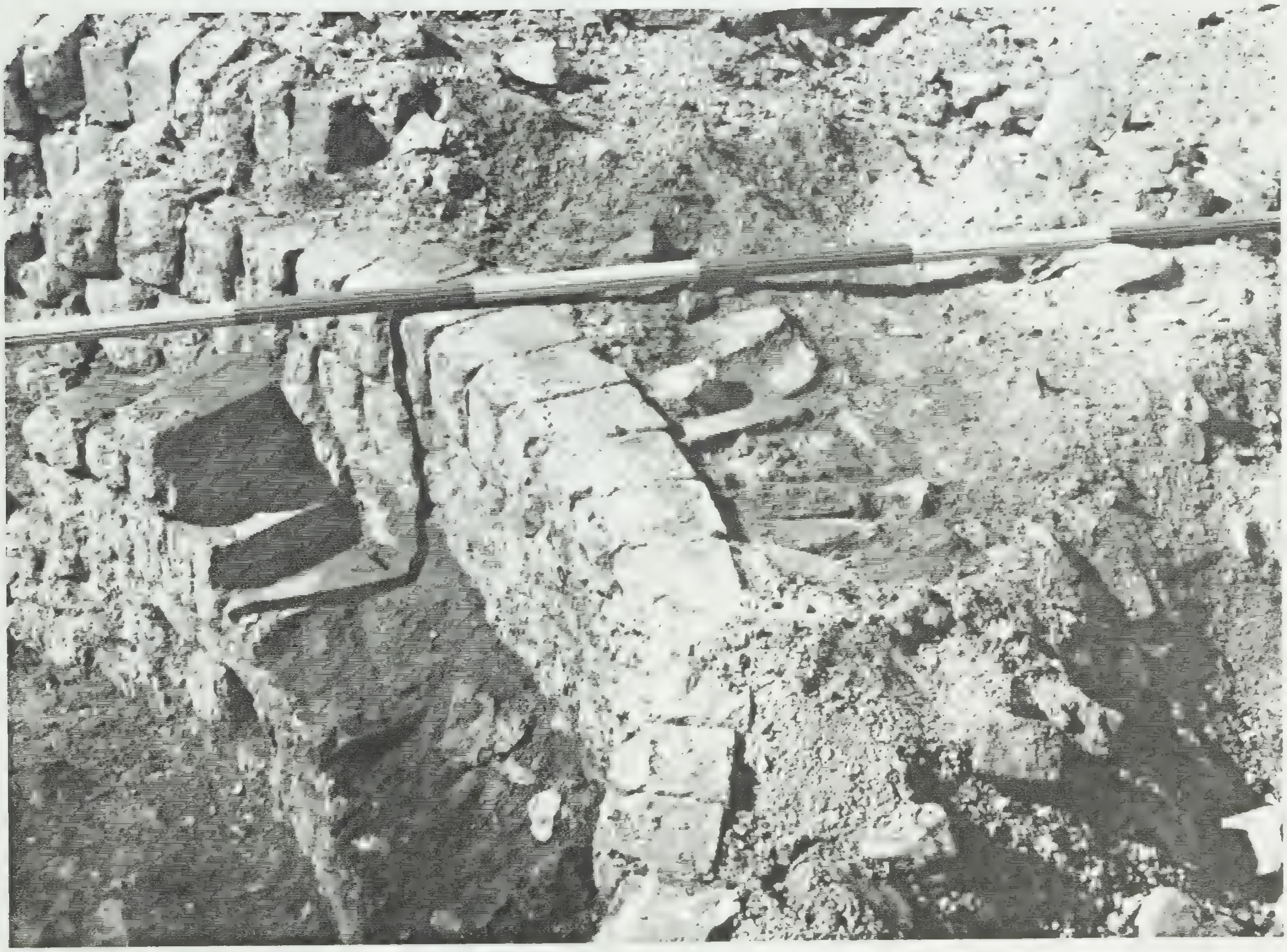

Plate 27: Kiln Two
Detail of the refractory brick lining, July 11, 1994. The two layers on the left had roughly equally vitrified surfaces and were not fused to each other. The secondary brick inner lining can be seen in the middle of the photo. The function of these two vitrified brick layers is unknown.

Plate 28: Kiln Two
Photomontage of the south furnace, July 11, 1994. There was no evidence of any roof or protective structure over this area. A small section of broken retaining wall can be seen on the left side of the photo. The stone relieving arch surrounding the furnace can also be seen. Note also the relatively small face stone compared to Kiln One [Plate 1].

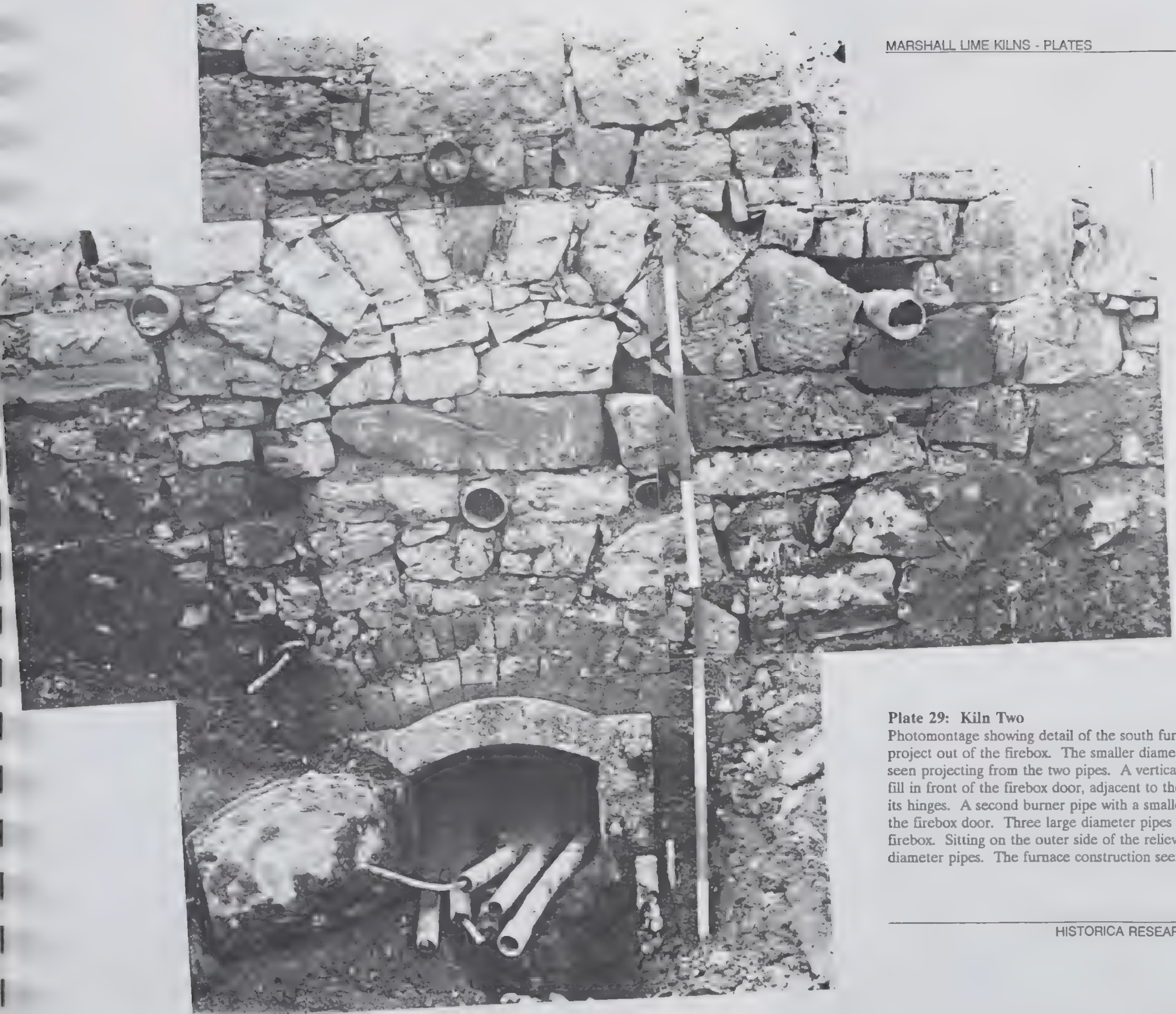

Plate 29: Kiln Two
Photomontage showing detail of the south furnace, July 11, 1994. Six burner pipes project out of the firebox. The smaller diameter inner (assumed) gas pipe can be seen projecting from the two pipes. A vertical pipe of unknown function rises out of fill in front of the firebox door, adjacent to the range rod. The firebox door is still on its hinges. A second burner pipe with a smaller diameter inner pipe is directly above the firebox door. Three large diameter pipes are also located directly above the firebox. Sitting on the outer side of the relieving and are an additional three, large diameter pipes. The furnace construction seems to be similar to Kiln One [Plate 15].

Plate 30: Kiln Two
Photomontage of the front of the kiln and access arch, July 12, 1994.

Plate 31: Kiln Two
Photomontage of the end of the access arch at the kiln wall, showing the poke holes at the top, two metal pipes of unknown function extending horizontally, the upper one of which is almost intact, the lower one having rusted through, July 12, 1994. In centre of the photo is a section of the railway rail, presumedly used for structural purposes. The draw hole is at the bottom.

APPENDIX A
CONSERVATION REPORT

APPENDIX A: CONSERVATION REPORT

by S. Maltby

1.0 INTRODUCTION

A stone mason and conservator were involved in this project to ensure the safe removal, transport and storage of the stones from the upper and lower arches of Kiln One. The following report includes a condition statement, summary of work carried out, problems encountered and recommendations for storage and re-erection of the stones.

1.1 Stone Condition

In general, the kiln stones are sound and in good condition. A few stones, namely those in the top course, below the large arch (Numbers I - III on plan), are split and cracked. These stones will need to be repaired (i.e., pinned and stitched together) if they are to be used in the reconstruction.

The kiln had been constructed using a lime mortar. A basic analysis of mortar showed a high concentration of lime (approximately 35%). This would indicate, considering the date of construction, that the original mix was probably 1:3 with one part lime putty (calcium hydroxide - $Ca(OH)_2$) and three parts aggregate (coarse sand). Most of the mortar has disintegrated and the joints are now filled with a crumbly sandy soil.

1.2 Work Summary

Once the backdirt was excavated and removed, the condition of the stones was assessed. A thick coating of hard clay, covering the front of the kiln, was removed thereby allowing for a closer examination of the stones and a better understanding of how the structure was constructed.

1.2.1 Recording

Prior to removal, the stones were traced, one to one, on sheets of Mylar^{tm} using indelible ink pens. It was felt that a one to one tracing would be more useful in the future in reconstructing the structure than a scale drawing. Due to the size of the kiln, three vertical strips of Mylar^{tm} were used. The strips overlapped one another allowing for proper registration in the future. A level base line and plumb lines were also included in each tracing to aid in proper reconstruction. Unfortunately, the large arch was inaccessible and as such could not be traced.

A tracing of the area below the smaller arch was also taken. This tracing was less detailed and outlined the areas that consisted of brick and stone and noted the location of the iron door surround of the draw arch. For several reasons, it is thought that in the future, new bricks should be used in reconstructing this area. Firstly, a number of bricks were missing or damaged (Plate

Plate 1: Area below the smaller arch. Note the condition of the bricks.

Plate 2: Per Neumeyer, stone mason, labelling each stone prior to dismantling.

1); secondly, it was felt that few of the bricks would survive dismantling intact; and thirdly, there was a concern that the bricks, which had been saturated during burial, may not survive long-term, outdoor storage. The long-term survival of the cast iron door surround also seemed unlikely as no special storage arrangements could be made for it.

1.2.2 Numbering

The stones from the large arch were labelled on the underside (the only clean surface available prior to dismantling) using red wax crayon. Arabic numerals were used for the large arch (I - XXXI). The stones of the smaller arch were marked with letters (D-R) and the stones around the smaller arch were labelled using Roman numerals. The Roman numerals and letters were chiselled into the top, front left hand corner (proper right front) of each stone as they were dismantled (Plate 2). Stones were numbered from left to right (when facing the arch) (Figure 1).

1.2.3 Dismantling

Dismantling an arch requires special care and preparation. An auxiliary support system is needed to support the arch after the keystone is removed. Traditionally, a cribwork or form is built to support an arch during construction. In this case, bales of straw were used to provide the requisite support and cushioning. The bales were piled up under the large arch and in the area in front of it prior to removing the keystone (Plate 3).

In preparation for removal, the soil around each stone was loosened and removed. This made it possible to slip a nylon sling around the stone (Plate 4). Each stone was then carefully lifted with the aid of a Gradall^{tm} (Plate 5) and placed on a wooden skid (Plates 6 and 7). The stones from the large arch fit on three skids (marked with a red star under an arch) and were kept separate from the stones belonging to the rest of the structure.

As suspected, retention of the brick and stone above the draw arch was not possible. Several bricks were retained as samples and have been stored with the stone. The iron door surround was securely bolted through several layers of brick and as such could not be removed in one piece.

1.3 Problems Encountered

The lower level of the kiln was quite damp and cool. The temperature gradient between the kiln and the air was such that condensation instantly appeared on the surface of the Mylar^{tm} when trying to trace the area below the small arch. This made recording in this area quite difficult. Condensate would form as quickly as one could wipe it off. In addition to this, a large rainfall midweek flooded out the area (Plate 8). The site was pumped out on several occasions but to

Figure 1: Labelling System for Dismantled Stones.

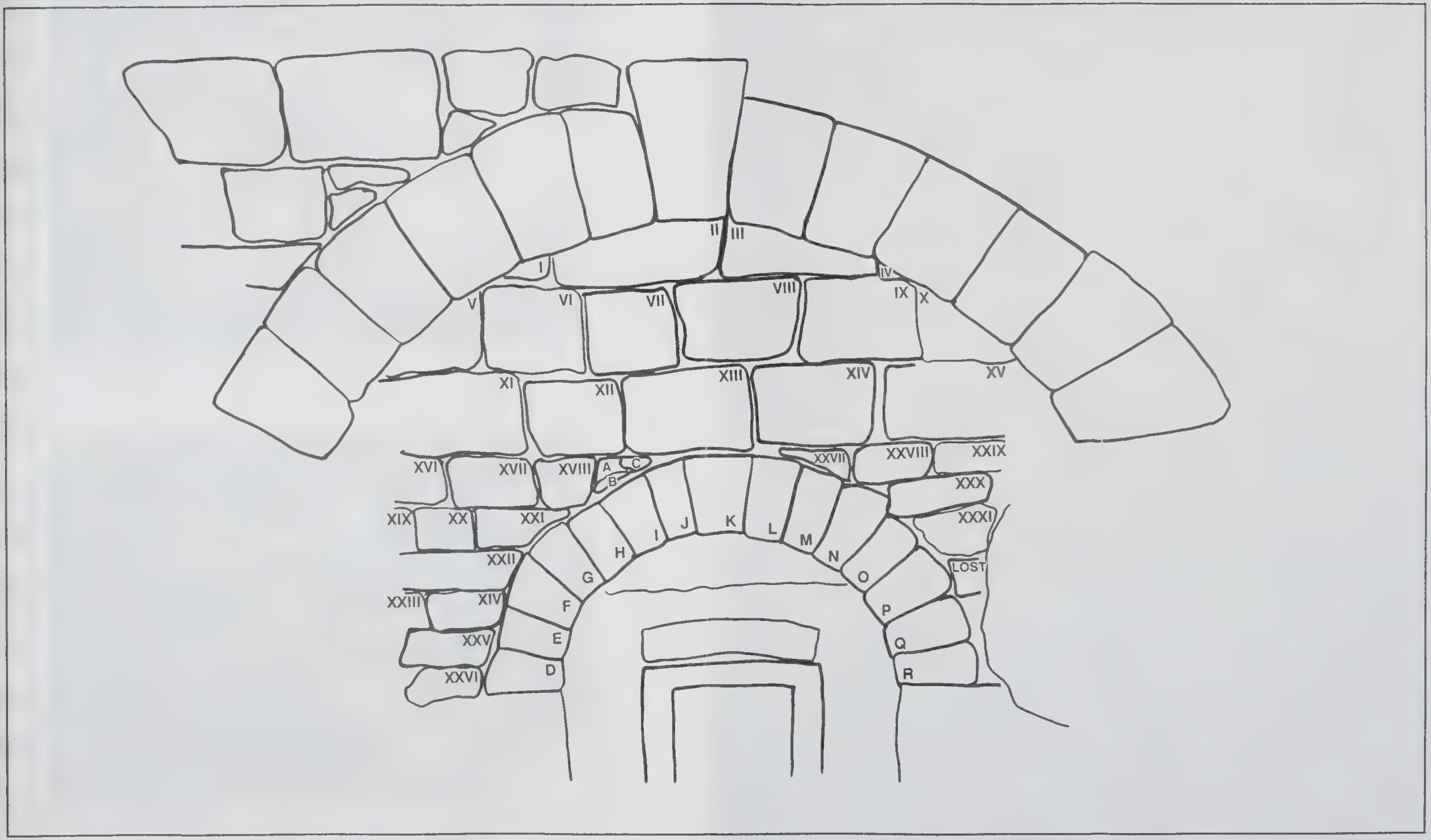

Plate 3: Bales of Straw used for support and cushioning during the dismantling.

Plate 4: Installing the nylon sling.

Plate 5: Lifting the keystone with the Gradall[tm].

Plate 6: Placing the keystone on a wooden skid.

Plate 7: Arranging stones on skid.

Plate 8: Flooding.

no avail. The bales of straw used to support the arches proved to be useful sponges absorbing considerable amounts of water. The flooding slowed the work and made it more treacherous.

2.0 RECOMMENDATIONS

2.1 Recommendations for Long-Term Storage

The stones should be stored off the ground, on skids.

Their security is also of concern. Signs should be erected that clearly state to whom the stones belong and that the storage area has access restricted to authorized personnel only.

An inspection schedule should be setup so that several times during the year, the stones are checked to ensure that they are still secure.

2.2 Recommendations for Re-Erection of the Kiln

Ideally, the individuals that dismantled the kiln should be retained to reinstate it. They should work with the design team to ensure that their design respects the integrity of the original structure. For example, the arch was originally buttressed or supported by the bedrock on either side. The design of the commemorative monument will need to provide the same sort of support in order that the arch will be stable.

The condition of the stones should be assessed prior to be being re-erected. Damaged stones should be repaired or replaced if considered unsound. The stones should be laid using a lime mortar similar to the one used originally. Commonly available cement mortars should be avoided as they are too hard and will shorten the lifespan of the stones. However, it should be noted that building with lime mortar will place more restrictions on the scheduling of the construction of the monument. Lime mortars need sufficient time to setup and cannot be used effectively at lower (i.e., freezing) temperatures.